TORT OF INVESTIGATION NO. 18 1953

STATE OF ILLINOIS

WILLIAM G. STRATTON. Governor

# *The Silting of Lake Carthage*

## CARTHAGE, ILLINOIS

J. B. Stall, G. R. Hall, S. W. Melsted and E. L Sauer

A Cooperative Study by
Illinois State Water Survey Division, Soil Conservation Service
United States Department of Agriculture
and Illinois Agricultural Experiment Station
With Local Help From
City of Carthage, Water Department

DEPARTMENT OF REGISTRATION AND EDUCATION

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STATE WATER SURVEY DIVISION

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(Printed by the authority of the State of Illinois)

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# SUMMARY

1. Lake Carthage, the municipal water supply reservoir at Carthage, Illinois, was built in 1926. The lake has a drainage area of 2.9 square miles. The original reservoir surface area was 39.7 acres and the capacity was 132.8 million gallons.

2. The 1949 sedimentation survey of this reservoir showed a capacity loss of 1.03 percent per year. In 23.4 years, the lake had lost 24.1 percent of original capacity.

3. The City of Carthage was served from 1898 to 1926 by an underground water supply. In 1926,. the present Lake Carthage and filter plant were constructed and have served the city's water-supply needs up until the present time.

4. The City of Carthage has grown in population from 1,654 in 1890 to 3,214 in 1950. If Carthage continues to grow as other comparable Illinois cities have in the past the population served by the water system will reach 9,100 by the year 2000.

5. In the past, the per capita use of water in Carthage has varied from 21 gallons to 71 gallons per person per day. Considering per capita use to reach a maximum of 100 gallons per person per day in the future, municipal pumpage may reach 540,000 gallons per day by the year 1970.

6. As of 1952, Lake Carthage has sufficient capacity to satisfy the entire demands on the lake during a drought which can be expected once in four years. From this standpoint, the Lake Carthage situation seems very serious, and action will be necessary soon to prevent a water shortage.

7. The storage capacity displaced each year by sediment in Lake Carthage would cost about $950 to replace at the present time.

8. Chemical analyses of samples of the reservoir sediment show them to be quite acid and low in organic carbon and nitrogen, indicating that they are not predominately surface soil materials.

9. Poorly drained prairie soil-groups occupy a large portion of the watershed. The Herrick silt loam soil group occupies 63.5% of the area.

10. A conservation survey of the watershed shows that nearly 80% of the watershed area has less than 4% slope.

11. The survey shows that 86.6% of the watershed is considered safe for continuous cultivation if conservation measures are instituted. At the time of the survey, 98.1% of the land was being cultivated.

12. The conservation data indicate that a disproportionate amount of moderate and severe erosion was found in pastures. Productivity of permanent pastures in the area probably is less than 50% of that which reasonably could be expected. Reseeding, fertilizing and mowing are needed to gain the potential yield from these pastures.

13. Indications are that sheet erosion furnishes 82% of the total sediment reaching the reservoir and that gully erosion produces 18% of the sediment.

14. A watershed treatment program in the Lake Carthage watershed which includes conservation farming methods and gully-control measures, could probably reduce the total sediment reaching the lake by 67.7%.

15. An important step in establishing a soil conservation program in this area is soil treatment, that is, the application of limestone, phosphate and potash in accordance with needs as shown by soil tests.

16. Studies of costs and benefits of contour farming in this area show that contour farming alone, contour strip cropping and terracing result in higher crop yields and do not increase the over-all cost of farm operation. Corn, soybeans, oats and wheat yields were increased 12%, 13%, 16%, and 17% respectively from contouring. Labor, power and machinery costs per crop acre averaged $1.58 lower at 1945 prices on the farms that were farming on the contour.

17. One study of a farm on land similar to that in the Lake Carthage watershed showed that during a ten-year period the crops grown yielded only 94% of the county average before a conservation program was started and 114% afterwards—a gain of 20%.

18. It is recommended that the City of Carthage engage a qualified professional engineer to investigate the adequacy of the present water supply system to furnish the present and future needs of the city and to report on the most economical method for maintaining an adequate water supply.

19. It is recommended that the City of Carthage undertake immediately the application of a watershed treatment program on the drainage area of Lake Carthage to reduce sedimentation and prolong the ultimate life of this lake and the length of time it can be used for the public water supply. It is suggested that this program be carried out by (1) financial assistance from the City to the local soil conservation district for intensified conservation efforts on this watershed, or (2) purchase of the watershed or much of the critical erosion area by the City for application of the needed conservation measures.

# THE SILTING OF LAKE CARTHAGE
# CARTHAGE, ILLINOIS

by
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## GENERAL

### INTRODUCTION

Need for Data. Nature's perpetual cycle of producing natural resources continues year after year furnishing man with an endless source of existence. We can not blame nature therefore for the scarcities which present themselves because of man's wastefulness. Two of our most basic resources, soil and water, are in many instances being depleted because of such wastefulness. The investigation discussed in this report is concerned with problems arising from loss of soil from a watershed, the consequent reduction in the productive capacity of the soil, and the resulting sediment deposition in a municipal reservoir, which reduces its capacity for storing the water needed by the City of Carthage, Illinois.

It would seem obvious that due to the increased demand for products of the soil, corrective measures should be taken to prevent the movement of this fertile topsoil from its place. Intensive agricultural use of the land in the past without adequate soil conservation measures has placed our resources in a very precarious position. Conservation of resources can not be concerned with present day needs alone, but must be considerate of future demands.

Most of the impounding reservoirs in Illinois have been constructed in the past two or three decades. Engineers chose logical locations for such reservoirs by considering the availability of water, distance from city, subsoil conditions for dam foundation, peak rates of runoff from watershed, population trends and cost of storage furnished.

Within the past few years it has become apparent that deposition of sediment in reservoirs can cause disastrous results. The sediment is rapidly replacing the space set aside to store water. As population and water consumption increase the need for a larger reserve of water storage will be required. This factor is usually taken into account in the design of a reservoir, but the rapid loss of storage space due to sedimentation if omitted from design will more than offset any such allowances. This would mean that in the event there was an increase in population or consumption the water supply would be inadequate. Many towns are today suffering from water shortages for this very reason even though their reservoirs were designed to handle water needs for years to come.

The seriousness of erosion in Illinois and the consequent rapid reservoir sedimentation led the Illinois Water Survey Division, the Illinois Agricultural Experime'nt Station and the Soil Conservation Service to join in 1936 in a cooperative study to determine the effects of different watershed and climatic factors on the rate of sediment production and the rate of sedimentation of reservoirs. The sedimentation survey of Lake Carthage was made under this program.

### SCOPE OF INVESTIGATIONS

Lake Survey. A preliminary survey was carried out on Carthage Reservoir in May 1949 to determine the need for a detailed survey and it was evident that the lake was suffering from a loss of capacity due to sedimentation. A detailed sedimentation survey was conducted at the Carthage Reservoir in July 1949. Surveys were made at the request of officials of the City of Carthage to determine the adequacy of the lake for water supply for the City.

The detailed survey was made by a field party of the State Water Survey Division and the City of. Carthage. Water depth and sediment thickness were measured along thirteen ranges on the lake. Cross-sections were used to determine the original capacity of the reservoir, the present capacity of the reservoir and consequently the volume of sediment in the lake. The surface area of the lake was determined from aerial photographs of the lake. In carrying out the survey a permanent marking system was installed so that in the future years resurveys may be made to measure the sediment accumulation at that time.

By analyzing the past trend in water consumption for the City of Carthage it was possible to determine the probable future water demand for the City. A study of this future water demand in conjunction with the present rate of reservoir storage depletion was made to show the approximate dates at which the lake will no longer be sufficent to supply the water needs of the city in case of droughts of various severities.

Watershed Survey. To determine the watershed sources from which the sediment originates, the Soil Conservation Service conducted a conservation survey of the watershed in 1949. These data on soils, slopes, land use, erosion and conservation practices give a very complete picture of the agricultural use of the farmlands on the watershed. An analysis of these data has been made to show specific problem areas where the soil losses from erosion are great and conservation measures would be particularly effective. By means of these data, it is possible to point out definite soil and water conservation measures that would effectively reduce the soil losses.

An additional study has been made by the Soil Conservation Service of the land use history of the watershed during the past twenty-four years while Carthage Reservoir has been in existence. This analysis shows the trend in land use of the watershed for this period. Its interpretation in light of the measured rate of sedimentation aids in developing recommendations for land use changes which would be most effective in reducing soil losses.

Sediment Samples. During the course of the survey a series of eleven sediment samples were taken from various parts of the lake by means of a special sampler. Chemical and physical analyses of these samples have been made by the Illinois Agricultural Experiment Station. An analysis of the texture, colloidal content, volume-weight and plant food constituents of the sediment gives significant indication of the watershed sources of the sediment deposited in the reservoir.

Interpretation of Results. The final interpretation of the silting problem at Carthage Reservoir has been made on the basis of the complete reservoir and watershed survey data by the three cooperating agencies. Results are presented so as to be most helpful to reservoir owners. Several remedial measures such as raising the spillway, dredging, and application of a complete watershed protective program are discussed.

## ACKNOWLEDGEMENT

City of Carthage. The agencies conducting this survey wish to acknowledge the generous cooperation of the municipal authorities of Carthage, particularly the City water department in authorizing and expediting this survey. Mr. Roy Metz, Waterworks Superintendent, was most helpful at all times in aiding the conduct of the survey.

State Water Survey Division. The survey of this reservoir was carried out by a field crew of the State Water Survey Division consisting of J. B. Stall, Chief of the party, T. E. Young and J. R. Singer, Engineering Assistants. The computation of the volume of water and sediment in the lake was carried out in the office. The compilation of the engineering sections of this report plus the preparation of the report for publication has been done by Mr. Stall under the supervision of H. E. Hudson, Jr., Head, Engineering Sub-Division.

Soil Conservation Service. Various officials of the U. S. Department of Agriculture, Soil Conservation Service have contributed to this study in many ways. The Sedimentation Section of the Office of Research in Washington furnished the specialized field equipment and aerial photographs for the survey work. Mr. L. C. Gottschalk, Head of the Sedimentation Section, gave technical assistance to the field party during the conduct of the survey and to the authors in the preparation of this report.

Mr. B. B. Clark, State Conservationist, cooperated by authorizing the conservation survey of this watershed by Soil Conservation Service personnel and was helpful in many ways to the authors in the preparation of the report. The field work of the watershed survey was carried out by Mr. A. A. Agathen, Soil Surveyor, during 1949. Mr. A. A. Klingbiel, State Soil Scientist, aided in the analysis of the watershed survey data.

Mr. G. R. Hall, Sedimentation Specialist, Milwaukee Regional Office, prepared the watershed section of this report including the conservation program recommendation for the watershed.

Dr. E. L. Sauer, Research Project Supervisor, Soil Conservation Service and Illinois Agricultural Experiment Station cooperating, carried out the study of land use and conservation history of the watershed. This study entailed both field visits and study of public records and their interpretation. Dr. Sauer also prepared the data in this report concerning the costs and benefits of conservation.

Illinois Agricultural Experiment Station. Samples of sediment in the lake were procured by the field party. These samples were analyzed in the laboratory of the Illinois Agricultural Experiment Station. The interpretation of these analyses and the preparation of the section of this report dealing with the sediment samples were carried out by Dr. S. W. Melsted, Associate Professor of Soil Analysis.

Hancock County Soil Conservation District. The directors of the Hancock County Soil Conservation District have aided this study by authorizing the use of personnel assigned to the District for carrying out the conservation survey of this watershed.


# RESERVOIR

## GENERAL INFORMATION

Reservoir. The reservoir is located about one mile northwest of the City of Carthage in the west half of Section 13, T. 5 N., R. 7 W. The dam is located in the northeast corner of the northwest quarter of Section 13. The reservoir extends approximately 4,000 feet generally south from the dam with one major side-arm extending west from the dam about 2,000 feet. The lake has a width of approximately 500 feet at the dam and the major arm has a width of about 250 feet. The general location of the reservoir with respect to the city of Carthage is shown in Figure 1. The lake is located on a tributary to Long Creek which flows east from the lake into the LaMoine River and thence southeastward into the Illinois River.

Dam. The dam extends in a generally northwest-southeast direction and has a total length of about 500 feet. The upstream face of the dam is faced with concrete to prevent wave erosion. A concrete spillway having a total length of about 65 feet is located at the southeast end of the dam. The waterworks intake is located near the dam.

Watershed. The reservoir has a total watershed area of 2.90 square miles. The watershed extends generally west and south from the lake.

## METHODS OF SURVEY

Range System. In determining the original (1926) and the present water and sediment volumes the range method of survey was utilized. This method of survey was developed by the Soil Conservation Service and is described in detail in their Bulletin No. 524 "Silting of Reservoirs."[1] The record of sedimentation in this lake is based on a system of 13 sediment ranges which were established by the field party for the purposes of this survey. The location of the range system on the lake is shown in Figure 2.

The base map for this survey consisted of an enlarged aerial photograph having a scale of one inch equals 200 feet. All survey stations were located on the map by means of visual observation of various topographic features. These locations were checked in the course of the survey by means of planetable and telescopic alidade. All triangulation stations and range ends were marked permanently in the field with concrete posts 4½ inches square and 4½ feet long. These posts were set into the ground with about one foot exposed. Station identification numbers were stamped permanently into the brass caps contained in these posts. This permanent marking system will be of value in the future when it becomes desirable to relocate the present sediment ranges to make a resurvey of Lake Carthage along these same ranges.

Measurement of Sediment. Along each sediment range at intervals of 25 feet the water depth and sediment thickness were measured with a sounding pole. This consists of a 1½-inch diameter calibrated aluminum pole constructed in sections to give a total length of 30 feet. This pole is shown in use in Figure 3. The pole is lowered into the water until it strikes the top of the sediment deposit and thus the present water depth is measured. The pole is then thrust on through the soft sediment until it strikes the hard soil of the original reservoir bottom. In this manner the present water depth and the sediment thickness are measured. As the boat is rowed across the range a cross-section of water depth and sediment thickness is obtained. A total of 186 sediment measurements were made on the 13 ranges on Lake Carthage.

Deltas. The surface area of the reservoir had been reduced very noticeably at the heads of the two main arms of the lake. The loss of surface area in the reservoir as a result of this delta formation was determined by remapping the present water line at the upper end of these arms. The volume of these deposits was calculated by use of the range formula which was used on all segments of the lake. The deposits in these areas which occurred above spillway crest elevations were not considered large enough to be mapped and calculated separately.

[1] Eakin, H. M., Silting of Reservoirs, U. S. Department of Agriculture Technical Bulletin 524, Revised by C. B. Brown, 168 pp. illustrated. Washington, U. S. Government Printing Office, 1939. Appendix.

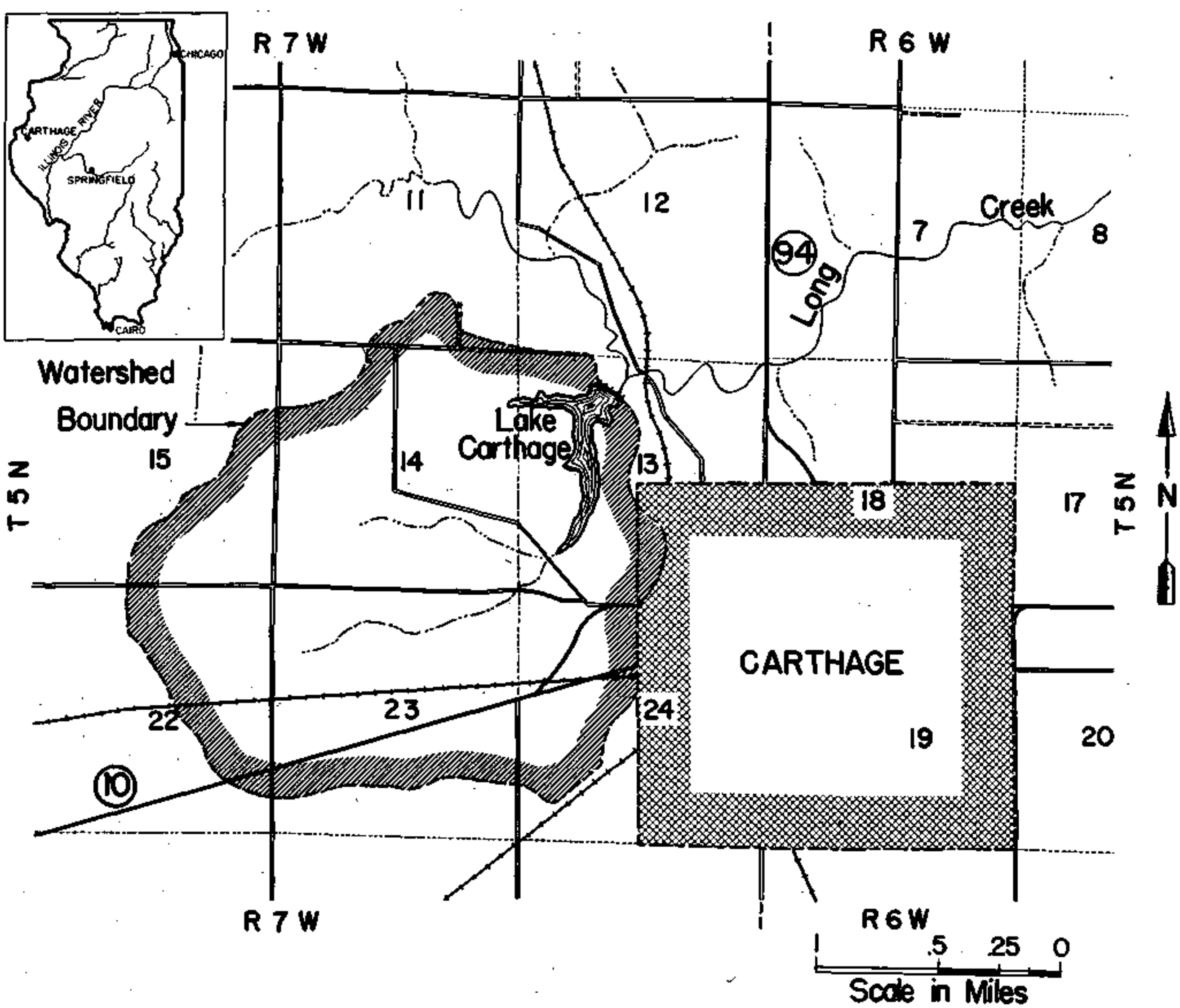


FIG. 1. LAKE CARTHAGE LOCATION.

## SEDIMENTATION IN THE RESERVOIR

Summary of Data. Table 1 is a summary of the sedimentation data obtained from this survey of Lake Carthage together with data derived therefrom which are pertinent to the sedimentation problem in this lake. Several of the significant findings shown in this summary are:

1. At the present spillway crest elevation the surface area of the reservoir has been reduced from 39.7 acres to 36.1 acres in the 23.4 years which the lake has been in existence.
2. The capacity of the reservoir for water storage has been reduced from 132.8 million gallons to 100.8 million gallons, or 24.14 per cent.
3. The sediment accumulation in the lake represents an average annual rate of sediment production of 93.3 cubic feet per acre from the watershed area.

Discussion of Lake Sedimentation. The total volume of sediment deposited in a reservoir is in general dependent upon three factors:

1. The total amount of soil which is removed from the lands of the watershed by erosion.
2. The effectiveness of the stream system within the drainage area in transporting the soil particles from the land to the reservoir.
3. The effectiveness of the reservoir itself in trapping and .retaining the sediment which flows into it.

The first of these items has been studied in detail for the Lake Carthage watershed and is discussed in a later section of this report. The effectiveness of the drainage system in transporting sediment to the reservoir depends on the hydro-physical characteristics of the watershed. Channel density is often used as a measure to express this. Authoritative authors in the field of reservoir sedimentation have selected the ratio of reservoir capacity to the total drainage area as a significant ratio for use in comparing different reservoirs regarding the third item mentioned above.[2] The capacity-watershed ratio, or C/W ratio, is usually expressed in units of acre-feet of storage per square mile of drainage area. Other factors being equal, the C/W ratio reflects the detention time or the total period of time that the waters from the watershed are stored in the lake. If the waters of the inflowing stream are detained in the lake for a long period of time all of the suspended sediment particles including clay and colloids have time to settle out and deposit on the bottom of the lake whereas, if the waters are retained in the lake for only a few days only the coarser particles such as sand, silt and coarser clays have time to settle out.

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[2] Brown, Carl B., The Control of Reservoir Silting, U. S. Department of Agriculture. Misc. Pub. No. 521, Washington, D. C, 1944.

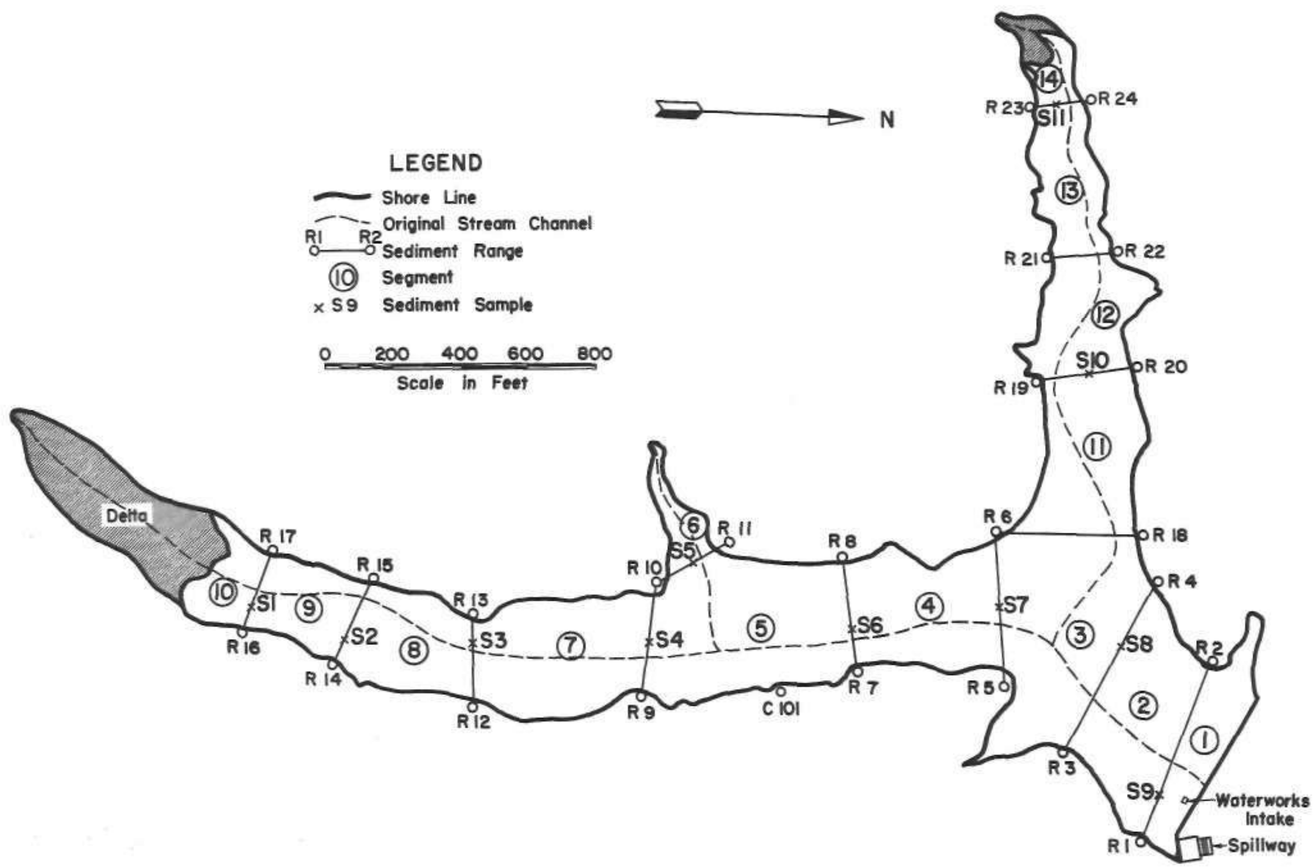



FIG. 2. LAKE CARTHAGE—1949 SEDIMENTATION SURVEY.

It is noted from Table 1 that Lake Carthage was designed and constructed with an original capacity-watershed ratio of 138 acre-feet per square mile.

In Table 2 the sedimentation results of Lake Carthage are shown in comparison to several other Illinois reservoirs that have recently been surveyed.

From the above discussion it is noted that with a given unit rate of sediment production a low capacity reservoir on a large watershed area will lose capacity much faster than a high capacity reservoir on a small watershed. It will be noted from Table 2 that reservoirs at Eldorado, Carbondale, and West Frankfort, all have capacity-watershed ratios of about 400 acre-feet per square mile. These reservoirs have annual capacity loses of 0.48 per cent, 0.63 per cent, and 0.33 per cent. On the other hand, Lake Carthage with an original capacity-watershed ratio of 138 has suffered an annual loss of capacity of 1.03 per cent. Conversely Spring Lake at Macomb with a much smaller original capacity-watershed ratio of 30-acre-feet per square mile has suffered a much larger rate of storage loss, 2.3 per cent per year. Figure 4 shows graphically the comparison of the annual rate of storage loss at Lake Carthage to the other reservoirs shown in Table 2.

Distribution of Sediment. Cross sections indicate a rather even distribution of sediment throughout the lake. The greatest loss of storage capacity in Lake Carthage has occurred at the heads of the two major arms of the lake in Segments 9, 10, and 13, 14 as shown in Figure 2. Segment No. 10 which contains a large delta area has lost a total of 75 per cent of its original capacity. Segment 9 has suffered a loss of 69 per cent of its original capacity. Segment 14 at the upper end of the smaller arm of the lake has lost a capacity totaling 58 per cent. Segment 1 nearest the dam had the lowest rate of capacity loss, losing only 13.0 per cent of its original capacity.

In Figure 5 is shown the cross-section of water depth and sediment thickness along range R 1 - R 2. This range extends across the main body of the lake immediately above the dam. (See Figure 2.) It is seen from the cross-section of range R 1 - R 2 that the original water depth of approximately 20 feet along the major portion of the range has been reduced by a deposition of sediment approximately 3 feet in thickness along the major portion of this range.

Figure 6 shows the cross-section of range R 9 - R 10 which extends across the main body of the lake in the central portion of the lake. It is seen from this cross-section that the original

FIG. 3. USE OF THE SOUNDING POLE IN MEASURING SEDIMENT.

TABLE 1

Summary of Sedimentation Data
Carthage Reservoir, Carthage, Illinois

| | Quantity | Units |
|---|---|---|
| AGE[1] | | |
| 1926-1949 | 23.4 | Years |
| WATERSHED | | |
| Total Area[2] | 2.90 | Square Miles |
| | 1969 | Acres |
| RESERVOIR | | |
| Area at spillway level | | |
| 1926 | 39.7 | Acres |
| 1949 | 36.1 | Acres |
| Storage Capacity at spillway level | | |
| 1926 | 406.3 | Acre-Feet |
| | (132.8 | Mil. Gal.) |
| 1949 | 308.2 | Acre-Feet |
| | (100.8 | Mil. Gal.) |
| Storage Capacity per sq. mile | | |
| 1926 | 138 | Acre-Feet |
| 1949 | 106 | Acre-Feet |
| SEDIMENTATION | | |
| Total Sediment | 98.1 | Acre-Feet |
| | (32.0 | Mil. Gal.) |
| Average annual accumulation | | |
| From entire drainage area | 4.19 | Acre-Feet |
| Per sq. mile of drainage area[3] | 1.42 | Acre-Feet |
| Per acre of drainage area[3] | | |
| By volume | 93.3 | Cubic Feet |
| By weight[4] | 2.50 | Tons |
| DEPLETION OF STORAGE | | |
| Loss of original capacity | | |
| Per year | 1.03 | Per Cent |
| Total | 24.14 | Per Cent |

[1] Storage began Spring, 1926. Date of Survey, August 17-23, 1949.
[2] Including area of lake.
[3] Excluding area of lake.
[4] Average specific weight of sediment equals 49.4 lbs. per cu. ft. based on 10 samples obtained in 1949.

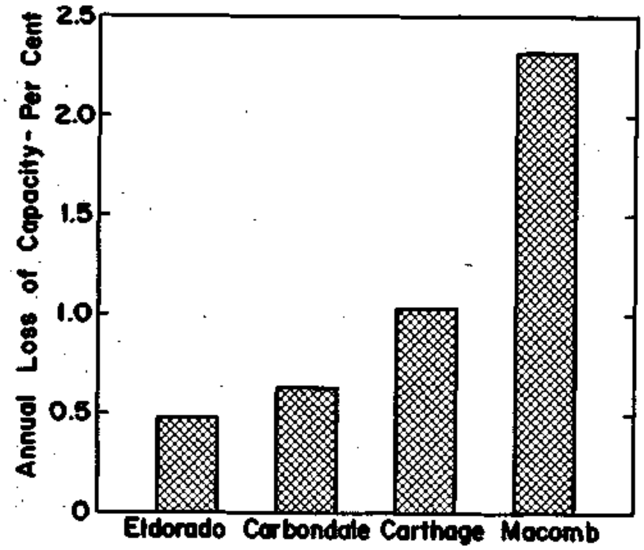



**FIG. 4. LAKE CARTHAGE STORAGE LOSS COMPARED TO OTHER ILLINOIS RESERVOIRS.**

water depth was approximately 13 feet along the valley flat and that the original stream channel had a total depth of about 18 feet. Sediment has been deposited along this range to a depth of about 3 feet for the entire range, the deposit being slightly deeper in the old stream channel.

In Figure 7 is shown the cross-section of Range R 16 - R 17 which extends across the lake at the extreme upper end as shown in Figure 2. In this part of the lake the total original depth of the water was approximately 6 or 7 feet. This has been reduced, however, to a depth of only about 2 feet at the present time. It is in this portion of the lake that a major percentage loss has taken place.

TABLE 2

Lake Carthage Sedimentation Compared to Other Illinois Reservoirs

| | Eldorado Reservoir | Lake Carthage | Carbondale Reservoir | W. Frankfort Reservoir | Spring Lake Macomb |
|---|---|---|---|---|---|
| Watershed area | | | | | |
| Sq. Mi. | 2.23 | 2.90 | 3.10 | 4.03 | 20.2 |
| Original Capacity | | | | | |
| Acre-feet | 844 | 406 | 1386 | 1608 | 607 |
| Mil. Gal. | 258 | 133 | 453 | 526 | 198 |
| Original C/W ratio | | | | | |
| Acre-Feet per Sq. Mi. | 453 | 138 | 462 | 399 | 30 |
| Age, when surveyed | | | | | |
| Years | 29.0 | 23.4 | 22.1 | 22.9 | 20.4 |
| Total loss of capacity, Per cent | 14.0 | 24.1 | 13.9 | 7.5 | 47.3 |
| Annual loss of capacity | | | | | |
| Acre-feet | 4.1 | 4.2 | 8.8 | 6.0 | 14.2 |
| Mil. Gal. | 1.3 | 1.4 | 2.9 | 1.9 | 4.6 |
| Per cent | 0.48 | 1.03 | 0.63 | 0.33 | 2.3 |
| Annual sediment production | | | | | |
| Cubic feet per acre | 149 | 93 | 208 | 109 | 48 |
| Tons per acre | 5.0 | 2.5 | 7.7 | 4.0 | 1.4 |

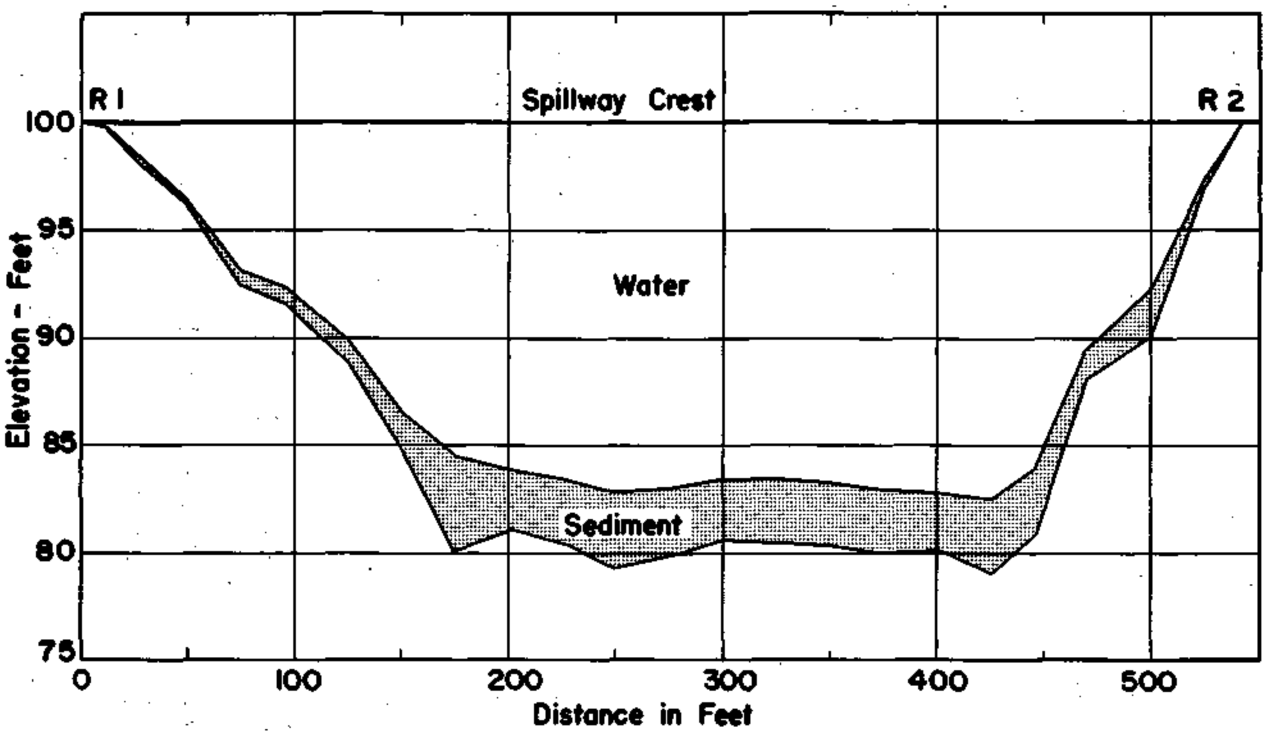



FIG. 5. CROSS SECTION OF RANGE R1-R2.

HISTORY OF THE CARTHAGE WATER SUPPLY

Period 1890-1925. Efforts to develop a public water supply for the City of Carthage were begun about the year 1890. At this time a well was drilled to a depth of about 1700 feet. This well-did not provide satisfactory water however and.it was abandoned. In 1898 another well was drilled, this to a depth of 1000 feet. This well was located about one block from the Courthouse square. Although the water from this well was highly mineralized it furnished the entire public supply for several years. Mineral analysis of the water taken from this well in. 1912 showed a total hardness of 741 parts per million, a total mineral content of 2677 parts per million.

In 1912 a new well was drilled at a location 25 feet north of the 1000-foot well. This new well was drilled to a depth of 847 feet. The mineral analysis of a water sample obtained from this new well May 1923 showed it to have a total hardness of 632 parts per million and a total mineral content of 2682 parts per million.. After the completion of this new well, it was used as a major source of supply for the city. Water from the new well reportedly had a more agreeable taste and tarnished fixtures less than did the water from the old wells.

The two wells owned by the City served to furnish the entire public supply for several years. However, in 1919 Mayor W. H. Hartzell and the members of the city council began to investigate the possible improvement of the City's supply. In July 1919, the city council passed a resolution employing the firm of Fuller and Beard, Consulting Engineers of St. Louis, Missouri to make a rather complete study of the water works situation. The City requested the engineers "to prepare a report with your recommendation as to the best source of water supply for the City of Charthage and suggest the design and capacity of the pumping plant and equipment; to prepare a plan of the City of Carthage showing the proposed extension of water mains with the location of the valves and fire hydrants and such other incidentals as are necessary to make a complete waterworks improvement."

In making their study the Fuller and Beard engineers investigated the possibility of a water supply from wells and

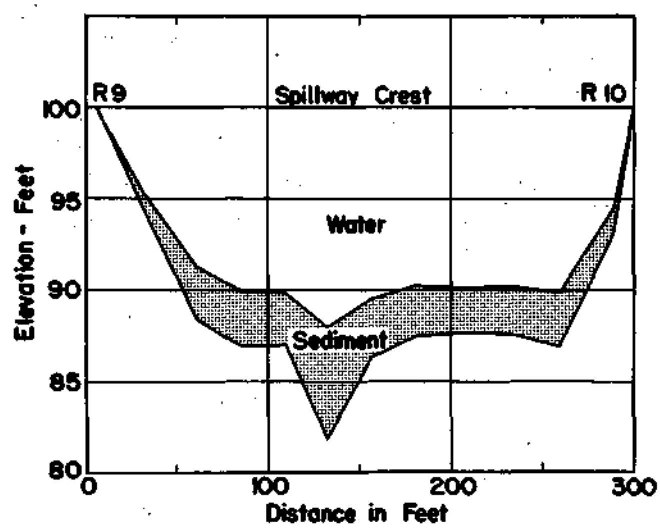



FIG. 6. CROSS SECTION OF RANGE R9-R10.

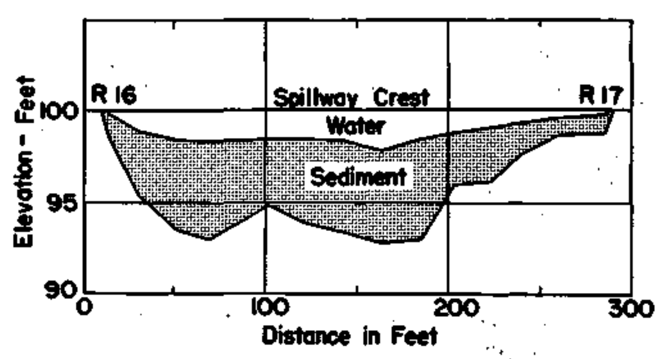



FIG. 7. CROSS SECTION OF RANGE R16-R17.

from several suface water sources. Their report stated: "As for the possibility of securing an adequate supply of a good potable water from wells within the vicinity of Carthage, you, as well as your neighboring cities of Macomb and Mt. Sterling, have well demonstrated it is not practical; that the water obtained from wells 200 feet deep while of a fair quality it cannot be obtained in sufficient quantity to supply your needs and the water from deeper wells is so mineralized as to make it unfit for domestic use."

As one possibility, the Fuller and Beard engineers suggested the construction of a channel dam on the main stem of the Lamoine River approximately 5½ miles east of Carthage. Their second proposal suggested the construction of an impounding reservoir on Long Creek about one mile north of the present city of Carthage. The location of this dam would be approximately one-fourth mile west of the present State Highway No. 94, on the Long Creek. This report recommended the construction of the reservoir on Long Creek. This reservoir would have a capacity of 40 million gallons and have a drainage area of about 12 square miles.

The report gave the following cost estimates: The total cost of dam and filter plant and pipe line construction on the Lamoine River site, $122,934. The total cost of the dam, lake, filter plant and pipe line construction on the Long Creek site, $74,240, and in either case an estimated cost of extensions to the city distribution system, including an elevated tank, $49,288.

Upon receipt of this report by the City officials, no definite action was taken, the primary consideration probably being that the costs were considered prohibitive.

1925-Present. In 1925 the City contracted for the construction of the present Lake Carthage and water filtration plant. The lake and treatment plant were designed by the Caldwell Engineering Company of Jacksonville, Illinois. The treatment plant is located near the west end of the dam and treatment consists of coagulation, filtration', and chlorination. The plant is connected to the city by means of an 8-inch diameter pipeline. An elevated steel tank of 80,000 gallons capacity was constructed at this time on city property at the site of the old waterworks within the city.

In 1949 several improvements and additions were made to the water treatment plant. This work was carried out with the advice of the Pappmeier Engineering Company of Galesburg, Illinois. At present the treatment plant has a rated capacity of 720,000 gallons per day. An analysis of a water sample collected from Lake Carthage in 1948 showed a total hardness of 100 parts per million.

The ownership of the waterworks of Carthage has been with the municipality since its very beginning.

## INCREASE IN WATER CONSUMPTION

General Considerations. The future demand for water in the Carthage area is dependent upon many factors such as the presence and possible expansion of water-using industries, the location of new industries in the area, the increase in population, the water rates, the water quality, and the adequacy of the water supply. A city of limited water supply is a city of limited growth and likewise the early development of the water resources of an area stimulates the economic growth of the area.

Population Trend. The U. S. Bureau of Census figures show that the population of Carthage has increased from 1654 in 1890 to 3214 in the year 1950. This increase has been plotted in Figure 8. The future growth of the City of Carthage to the year 2030 as shown in Figure 8 is based on consideration of the past growth of other cities in the area. It is believed that the most reliable method for determining future growth of the City of Carthage is to compare it to the growth of other comparable cities in this part of Illinois which have experienced such growth in the past. The past population curves for the cities of Macomb, Canton, Sterling and Monmouth are shown in Figure 8. By this means it is seen that the population of Carthage may reach 6,500 by the 1980, 9,100 by the year 2000, and 14,000 in the year 2030.

Water Consumption per Capita. The total municipal pumpage in any year divided by the population gives the rate of per capita water consumption. Factors affecting per capita consumption are the same as those affecting the total water demand. In the past, repeated studies have been made correlating the per capita consumption and the total population. A recent study in Illinois has shown that the per capita consumption of water is not necessarily a function of the total population of the community.[3] The per capita consumption is most closely correlated with the net effective family buying income of the area. If the economic development of the area increases this average purchasing power, then the per capita water consumption can be expected to increase, otherwise not. Table 3 shows the variation in consumption per capita at Carthage in past years. This has varied from a low of 21 gallons per person per day in 1920 to a high of 71 gallons per person per day in 1950. While per capita consumption has shown a steady increase over the period shown in Table 3 it is not believed that such a trend can continue indefinitely. For estimating future water demand a constant value of 100 gallons per person per day was used.

The values of future populations from the graph in Figure 8 multipled by the average daily consumption of 100 gallons gives the average annual pumpage to be expected in future years. Calculated in this manner the total municipal pumpage may reach 540,000 gallons per day by 1970, and 760,000 gallons per day by 1990. The assumption that the total per capita consumption will not increase above 100 gallons per day is considered conservative. There remains the possibility however that this figure may be exceeded. This would increase the future water requirements of the city.

TABLE 3
Water Consumption at Carthage

| Year | Population | Total Pumpage 1000 Gal. Per Day | Gallons per Day Per Capita |
|---|---|---|---|
| 1920 | 2129 | 45 | 21 |
| 1925 | 2175 | 55 | 25 |
| 1930 | 2240 | 62.4 | 28 |
| 1935 | 2410 | 81.2 | 34 |
| 1940 | 2575 | 109.3 | 42 |
| 1945 | 2895 | 129.3 | 51 |
| 1950 | 3214 | 221.9 | 71 |

## RESERVOIR OPERATION AND NEED

General. The function of any water-supply impounding reservoir is to store runoff from the watershed during wet periods when the stream flow exceeds the consumption. The water thus stored is available for use during dry periods when the flow of water in the stream is insufficient to furnish the user's need. Consequently, to obtain the full value from a reservoir, it should be designed so that the runoff coming into the reservoir is large enough to overbalance the consumption plus the losses from evaporation and seepage. The storage volume of the reservoir should be large enough to fulfill all needs during the driest season for which it is designed.

[3] Larson, B. O. and Hudson, H. E., Jr. Residential Water Use and Family Income. Journal American Water Works Association, August, 1951, Vol. 43, No. 8.

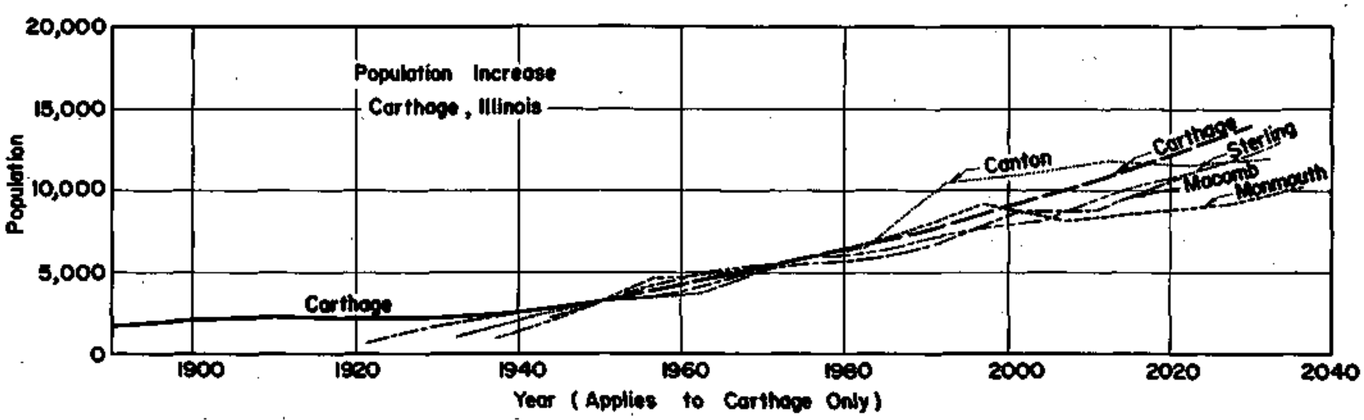



FIG. 8. CARTHAGE POPULATION TREND.

The best indication of the usefulness and the need of a water-supply reservoir is the fluctuation of the water level in the lake. Ever time the water level is drawn down in the reservoir, demand is exceeding the inflow. This means there would be a water shortage if the lake were not present. Likewise the best indication of the impending inadequacy of a reservoir is the occurrence of serious drawdowns during dry periods when inflow is small and consumption is large. Sediment deposits steal needed storage space. This loss of water storage capacity causes progressively heavier drawdowns during dry periods.

Under limiting conditions of precipitation, runoff, evaporation, seepage, availability of land, and prevailing rate of sediment production, the problem of developing a dependable water supply is not a simple one. If the reservoir capacity is too large in relation to the size of drainage area, it may never fill to capacity, thus representing an economic loss to the owners. If the reservoir capacity is too small, loss of capacity due to sedimentation will probably be high and the reservoir will rapidly become useless.

Remaining Useful Life of the Reservoir. The storage capacity of Lake Carthage is now being reduced by 1.03 per cent per year as shown in Table 1. Figure 9 shows graphically this reduction in lake capacity assuming that the rate of deposition will continue at the present rate. It is seen from Figure 9 that at the present rate of sedimentation, the capacity of the lake would be reduced to 87.5 million gallons in the year 1960, 77.1 million gallons by the year 1980, and 66.7 million gallons by the year 2000. As the storage capacity in the lake decreases and the total water consumption for the city increases, it is seen that at some time in the future a water shortage could occur. The lake owners who are faced with the problem of providing an adequate source of water supply must know the future date at which such a water shortage may occur in order that steps may be taken to prevent the water shortage. The total length of time for which the reservoir can furnish the total supply of water needed by the city is termed the "useful life of the reservoir." This term is used because at the end of this time the lake will no longer be able to furnish the total needs of the city.

A future water shortage will occur only during a dry period of such severity that the minimum inflow to the reservoir is insufficient to furnish the entire pumpage for the city plus the losses from evaporation and seepage. As such a shortage nears, the water level in the lake is drawn down. Past records at Lake Carthage show that only in the past few years has the water level been drawn down seriously. The "critical usage period" or the length of time in months during which the water level may be drawn down and eventually the lake emptied, is dependent upon, first of all, the total water demands as explained above. The second major factor affecting the occurrence of the water shortage is the precipitation expected on the watershed and the flow characteristics of the streams which feed the lake.

Stream Flow Variability. At the present time there are in existence approximately 170 gaging stations on Illinois streams. After records at a particular station have accumulated for a number of years, an analysis is made of the flow characteristics of the stream at that point. Such flow records are extremely valuable in designing a reservoir, in determining the total flow which can be expected into a reservoir at a particular point on the stream. This stream-gaging work is carried out by the United States Geological Survey in cooperation with state and local agencies. The primary sponsor for stream-gaging stations in Illinois is the State Water Survey.

In a recent publication of the State of Illinois, a detailed analysis was made of the flow characteristics of twenty-eight Illinois streams.[4]

Very few gaging station records are available in Illinois on watersheds as small in size as the 2.9 square-mile watershed of Lake Carthage. However the method devised by Mitchell in the above publication was used to determine the probable flow characteristics of the Lake Carthage basin. As an index station in this stream flow analysis the 27-year record was utilized from the Lamoine River at Ripley covering the years 1921 through 1947. Although the total watershed of the Lamoine River station at Ripley is 1,310 square miles, this record was used to determine the flow characteristics of a much smaller watershed, namely the Gimlet Creek near Sparland, Illinois which has a watershed of 5.3 square miles. The Gimlet Creek station at Sparland was chosen because it was the smallest size basin on which records were available which would lend themselves to this type of analysis. The synthetic flow records from Gimlet Creek were used to determine the probable lo v flows on the Lake Carthage drainage area.

Drought Frequencies. In analyzing the severity of droughts it is common to refer to the various droughts as having an occurrence frequency; that is, a certain drought can be said to have a recurrence frequency of 10 years when such a drought occurs once during every 10-year period. Droughts of lesser severity can be expected at smaller intervals of 5, 3, or 2 years. The more severe droughts which furnish much less runoff may occur only once in 25, 50 or even once in 100 years.

Date When Water Shortage May Occur. The performance of Lake Carthage in furnishing the increasing municipal pumpage plus evaporation losses during low flow periods having various occurrence frequencies has been analyzed as a part of this study. The results of this analysis are shown in Figure 10. Reference to Figure 10 reveals that in the present year 1952, Lake Carthage is adequate to furnish the entire demands on the lake during a drought of such severity that it might occur once in every 4 years. By the year 1960, city pumpage demands

[4] Mitchell, William D., Water Supply Characteristics of Illinois Streams, State of Illinois, Department of Public Works & Buildings, Springfield, Illinois, 1950.

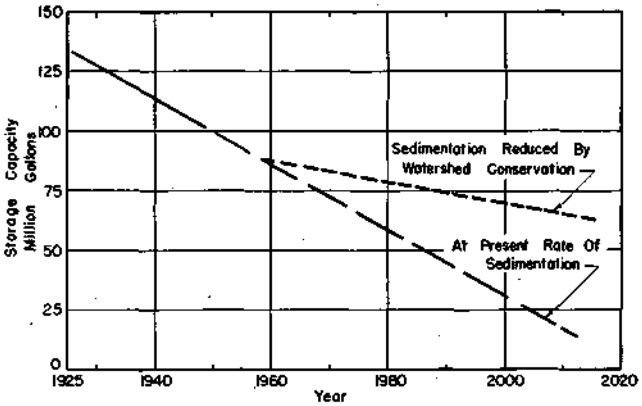



FIG. 9. **DECREASE IN STORAGE CAPACITY** DUE **TO** SEDIMENTATION—LAKE CARTHAGE.

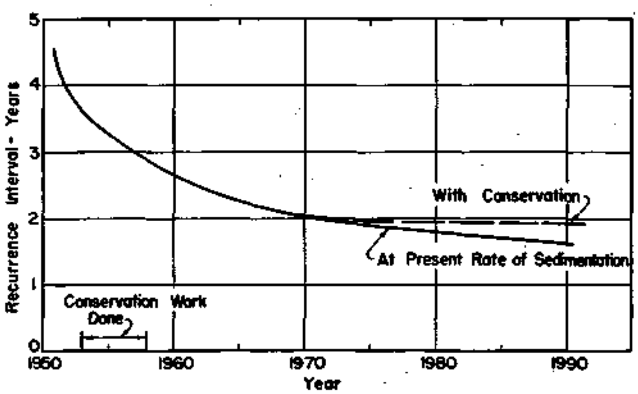



FIG. 10. RECURRENCE FREQUENCY OF DROUGHTS WHICH MIGHT CAUSE A WATER SHORTAGE AT CARTHAGE.

will probably have increased to a point where the total demand can no longer be furnished during a drought having a recurrence interval of 4 years. In 1960 the lake would be adequate to furnish the supply during a drought having a frequency of 2.8 years. By the year 1970 city pumpage will have increased and the lake capacity will have decreased to the point where the reservoir can furnish the water demand of the city only during a drought having a frequency of once every 2 years.

The situation depicted by Figure 10 is considered very serious in view of the fact that in the present year a water shortage may be expected to occur during a drought which can be expected any year within the next four years. In modern water supply planning, it is normally considered necessary to provide adequate storage to suit the needs of a municipality during a drought expected only once in 25 years or once in 50 years. It is not believed desirable for a municipality to remain dependent upon a source of supply which may be inadequate once in every four years or less. From this standpoint, the Lake Carthage situation seems very serious and action will be necessary soon to prevent a water shortage.

## ECONOMIC LOSS FROM SEDIMENTATION

At the time of the construction of the lake, in 1926, a bond issue of $77,000 was floated to cover the cost of the lake, the treatment plant and the eight-inch main connecting the treatment plant to the city distribution system. No breakdown is available stating the individual costs of the three items and so the actual cost of the lake itself is not readily available. For analysis purposes it is assumed that the total lake costs including land acquisition, clearing and dam and spillway construction amounted to $35,000.

The original lake capacity, as determined by the survey was 132.8 million gallons. If the lake cost $35,000 the original storage cost $263 per million gallons. This means that the sediment which has deposited in the lake each year Has destroyed storage space which cost $361. This amount of damage is occurring every year.

Replacement of this lost storage capacity as well as the building of additional facilities at present prices would be expensive. In 1926 when Lake Carthage was constructed the general cost of such work was much less than at present. One of the most widely used indices of such construction cost in the Engineering News-Record Construction Cost Index which is computed monthly and considers current prices of certain basic construction commodities such as cement, steel, labor, etc. In 1926 the Construction Cost Index was 210 (based on the year 1913 = 100)[5] and in March 1952 this index had risen to 551. In consideration of this increase in cost the Lake Carthage storage capacity destroyed each year would cost $947 to replace at the present time. Applying the same increase in cost figures to the original cost of the reservoir, the cost today to build a new reservoir of the same capacity would be $92,000.

## SEDIMENT CHARACTERISTICS

Analyses Made. Sediment samples were taken from severa locations within the reservoir, as shown in Figure 2. These samples were analyzed chemically for total carbon, total nitrogen, base-exchange capacity, total exchangeable- bases, pH, available potassium, and available phosphorus. The volume-weight and the percent of sand, silt, and clay were also determined. The data are given in Table 4.

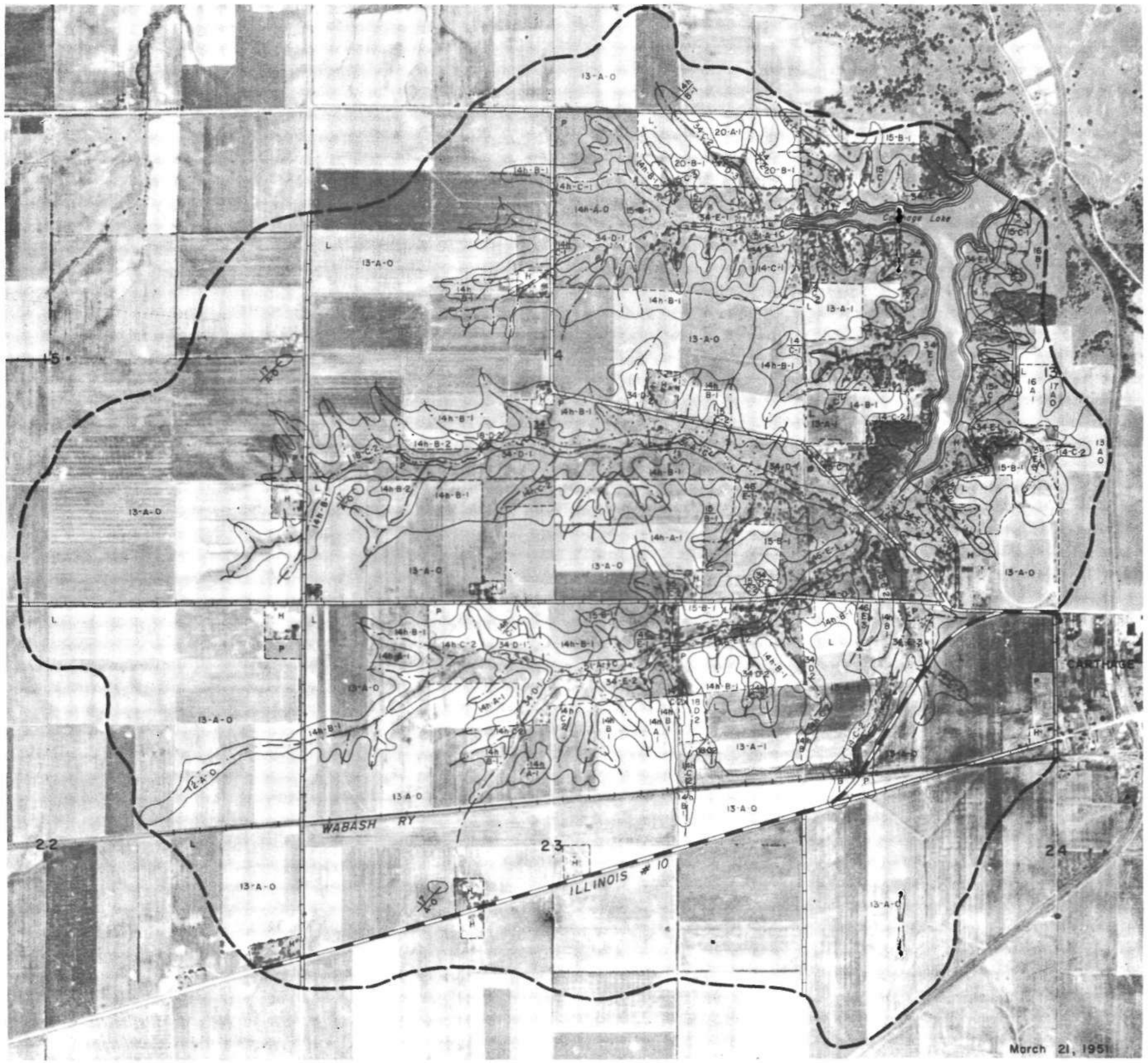
There is considerable variation in the chemical properties of these sediments, the areas represented by samples 1, 2, and 11 being low in total organic carbon and nitrogen as well as base-exchange capacity. These areas represent the coarser or sandier sediments in the reservoir where the stream waters with their incoming loads enter the main body of water in the reservoir. From these locations on downstream to the dam the sediments increase progressively in organic matter and nitrogen as well as in total clay content. Sediments entering the reservoir from the south, the region of sample 1, are much more alkaline than are those entering from the west, the region of sample 11. The sediments are, in general, quite acid and low in organic carbon and nitrogen indicating that they are not predominately surface soil materials.

The material accumulating in the reservoir is quite high in fertility. During its accumulation farmers in the watershed area have lost an equivalent of 5 tons of muriate of potash, 25 tons of superphosphate, and 40 tons of ammonium nitrate in the form of available nutrients contained in the sediments from the watershed. In terms of present-day prices of fertilizers, this represents an annual loss of over $200 worth of fertilizers from the watershed in the form of erosion.

The volume-weights, or densities, of the sediments vary with location in the reservoir. Sediments from areas of rapid change in the rate of flow of the incoming water, as represented by samples 1, 2, 5, and 11, are sandier and higher in silt than are the sediments from areas closer to the dam where the water moves quite slowly. In the dam area the sediments are low in volume weight and quite high in clay content. Therefore, considerable sorting of sediments has occurred within the reservoir. The rather high amounts of clay in the sediments represented by samples 6 to 9 are indicative of the slow movement of water through the main body of the reservoir.

[5] Engineering News-Record March 20, 1952, p. 31, McGraw Hill Publications, New York, N. Y.

HANCOCK COUNTY. ILLINOIS — R7W — U. S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE




Uncontrolled Conservation Survey Mosaic **Compiled by the Cartographic Division,**
Soil Conservation Service, Region III, Milwaukee, Wisconsin.
From USDA Aerial Photographs RX "1938" Hancock County, Illinois.
Conservation Survey by the Soil Conservation Service.

0 — 1/4 — 1/2 — 3/4 — 1

**Approximate Scale in Miles**

# CONSERVATION SURVEY LEGEND
# CARTHAGE LAKE
# HANCOCK COUNTY, ILLINOIS

## SOIL GROUPS

14,14h Moderately Well Drained Prairie Soils
18,34,15 Imperfectly Drained Soils
12,13 Poorly Drained Prairie Soils
46 Well Drained Timber Soils
16,20,17 Poorly Drained Claypan Soils
51 Bottomlands

## LAND USE

L Cultivated Land
P Pasture Land
H Farmsteads and Miscellaneous

## EROSION

+ and +C Deposition
0 No Apparent Erosion
1 Slight Erosion
2 Moderate Erosion
3 Severe Erosion

## SLOPES

A 0 to 1½ Percent
B 1½ to 4 Percent
C 4 to 7 Percent
D 7 to 12 Percent
E Over 12 Percent

FIGURE 11.

TABLE 4

Chemical and Physical Data on Lake Carthage Sediment Samples

| Sample Number | Volume Weight | Total Carbon (%) | Total Nitrogen (%) | Exchange Capacity m.e./100 | Total Exch'g'ble m.e./100gm. | pH | Sand (%) | Silt (%) | Clay (%) | Available Potassium lbs./acre | Available Phosphorus lbs./acre |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.97 | 1.55 | 0.144 | 22.5 | 23.7 | 6.3 | 0.8 | 63.4 | 28.7 | 300 + | 200 + |
| 2 | 1.09 | 1.28 | 0.110 | 17.7 | 17.8 | 6.0 | 1.1 | 63.6 | 25.2 | 300 + | 200 + |
| 3 | 0.75 | 1.72 | 0.152 | 29.4 | 25.8 | 5.4 | 0.1 | 53.8 | 38.6 | 300 + | 200 + |
| 4 | 0.74 | 2.06 | 0.178 | 32.5 | 28.7 | 5.7 | 0.1 | 48.2 | 44.0 | 300 + | . 200 + |
| 5 | 0.73 | 1.85 | 0.170 | 30.9 | 25.8 | 5.1 | 0.3 | 49.8 | 44.7 | 300 + | 200 + |
| 6 | 0.65 | 2.06 | 0.184 | 37.1 | 31.2 | 5.2 | 0.1 | 40.0 | 54.0 | 300 + | 200 + |
| 7 | 0.71 | 2.10 | 0.183 | 34.8 | 30.4 | 5.2 | 0.1 | 42.2 | 50.6 | 300 + | 200 + |
| 8 | 0.66 | 2.41 | 0.198 | 38.7 | 29.6 | 4.8 | 0.1 | 34.4 | 59.7 | 300 + | 200 + |
| 9 | 0.75 | 1.89 | 0.206 | 24.9 | 29.6 | 5.2 | 0.2 | 43.7 | 49.9 | 300 + | 200 + |
| 10 | 0.67 | 2.20 | 0.204 | 35.0 | 27.0 | 4.9 | 0.1 | 61.4 | 30.3 | 300 + | 200 + |
| 11 | 1.11 | 1.37 | 0.106 | 19.5 | 17.2 | 5.4 | 2.9 | 64.7 | 26.7 | 300 + | 200 + |

Origin of Sediment. The sediments entering the reservoir seem tobe of two distinct types. Material coming in at the south, as represented by sediment samples 1, 2, and 3, is quite high in pH and indicates that uhweathered loess must-be entering the reservoir along with surface soil. The somewhat alkaline nature of this sediment suggests that sheet erosion and the extension of existing small or shallow gullies working back into the watershed are the primary sources of the sediments entering at this point. Much of this material appears to be surface soil and unweathered loess.

In contrast, the sediments entering from the west, as represented by samples 5 and 11, are quite acid in character. Since these sediments are more acid than the normal surface soil and considerably more acid than the unweathered loess, they must be coming from the deeper more acid and weathered Illinoian till which is found below the loess: In this area of the watershed gully erosion extending down into the weathered Illinoian till appears to be an important source of sediment accumulating in the reservoir. Sediment control in the reservoir appears to involve the control of both sheet and gully erosion in the watershed.

## WATERSHED

### INTRODUCTION.

. Many watershed factors affect the rate of sedimentation of reservoirs. They include size of drainage area, topography, soil types, slopes, and land use. The.sources of sediment must be determined if an effective sediment control program is to be developed for the reduction of reservoir damages. Furthermore, the relative importance of the watershed factors must be examined in order to develop reservoir design data.

### PHYSIOGRAPHY

The watershed of Lake Carthage lies entirely within Hancock Country Illinois. Lake Carthage was built on a tributary of Long Creek in Section 13 Township 5 North, Range 7 West. Total watershed area is 2.90 square miles.

The watershed of Lake Carthage is located in the west central portion of the Galesburg Plain,[6] a minor division of the Central Lowland Province. It consists of a level to undulatory till plain in a late youthful stage of geologic erosion.

### SOIL GROUPS

The soils of the watershed were divided into six groups. There are three basic groups of soils in the watershed, upland prairie soils, upland timber soils and bottomlands. However, since there is no woodland in the watershed at the present time, a soils grouping was formulated to combine soils of similar land use capabilities rather than soils of similar origin.

[B] Leighton, M. M., Ekblaw, George E., and Horberg, Leland. Physiographic Divisions of Illinois. Illinois Geological Survey, Report of Investigations No. 129, 33 pages, illus.,Urbana, Illinois, 1948.

The conservation survey map of the watershed is shown in Figure 11. The largest groups of soils are the Virden and Herrick silt loam groups (Poorly Drained Prairie) as shown on Table 5. The Herrick silt loam group is the most extensive soil in the watershed, occupying 63.5 per cent of the area. Imperfectly drained soil groups mapped as Velma, Blair and Clinton-Mottled phase, silt loams, occur on 15.7 per cent of the area. The moderately well drained prairie soils (Harrison silt loam groups) occur on 15.6 per cent of the area. Poorly drained claypan soils (Berwick, Whitson and Dunkel silt loam groups) occur on 1.5 per cent of the area as do the well drained timber soils (Hickory gravelly loam group). Bottomlands (Huntsville loam and associated groups) occupy 1.9 per cent of the watershed.

In general the dark prairie soils are more fertile than the light-colored timber soils. The relative productivity of soils in Lake Carthage Watershed may be found in Table 6.

### SLOPES

Slopes influence the velocity of runoff and its ability to erode soil. In general, slopes are not steep in the Lake Carthage Watershed in comparison with watersheds of similar size in other parts of the state. From Table 7, it is calculated that 79.4 per cent of the watershed area has less than 4 percent slope. The degree of slope in any part of the watershed is related to the extent of development of the drainage system. The upland areas are level to gently sloping (A slopes). The gentle slopes of the upland area drop off into moderately sloping waterways and the side slopes of the waterways become progressively steeper as they approach the stream. The maximum steepness occurs along the valley sides of the main streams and entrenched tributaries. Of the total cropland in the area 93.3 per cent is located on slopes of less than 4 per cent. About 38.0 per cent of the pasture land is located on slopes of less than 4 per cent as shown in Table 9.

TABLE 5

Acreages and Percentages of Various Soil Groups in Carthage Watershed, Carthage, Illinois

| Soil Group | Area | |
|---|---|---|
| | (acres) | (per cent) |
| Moderately Well Drained Prairie | | |
| Harrison Silt Loam Group | 300.3 | 15.6 |
| Imperfectly Drained Soils | | |
| Velma Silt Loam Group | 16.3 | 0.9 |
| Blair Silt Loam Group | 194.1 | 10.0 |
| Clinton-Mott Phase Silt Loam Group | 92.6 | 4.8 |
| Total | 303.0 | 15.7 |
| Poorly Drained Prairie | | |
| Virden Silt Loam Group | 8.5 | 0.4 |
| Herrick Silt Loam Group | 1227.3 | 63.5 |
| Total | 1235.8 | 63.9 |
| Moderately Well Drained Timber | | |
| Hickory Gravelly Loam Group | 28.9 | 1.5 |
| Poorly Drained Claypan Soils | | |
| Berwick Silt Loam Group | 14.1 | 0.7 |
| Whitson Silt Loam Group | 13.5 | 0.7 |
| Dunkel Silt Loam Group | 1.6 | 0.1 |
| Total | 29.2 | 1.5 |
| Bottomlands | | |
| Huntsville Loam Groups | 35.5 | 1.9 |
| Entire Watershed | 1932.7 | 100.0 |

## PRESENT LAND USE

One of the more important factors that affect the rate of sediment production is land use. Three classes of land use, cropland, pasture and miscellaneous, were mapped in the conservation survey. Cropland is all land on which crops were grown at the time of the survey. It includes land in row crops, small grains and hay. Pasture is land in perennial grasses. Miscellaneous land consists of land used for farmsteads, roads or other purposes.

Land use in general is related to soil groups. Thus 98.6 per cent of the cropland in the watershed is located on soil groups 1, 2, and 3 (See Table 8). Cropland is confined primarily (93.3 per cent) to A and B slopes while pasture is fairly well distributed on all slopes. (See Table 9).

Table 10 presents a general summary of the capability of the lands of the watershed as compared to the present use of these lands. This shows that 86.6 per cent of the watershed is in land capability classes I, II and III which is considered safe for continuous cultivation. At the time of the survey, 98.1 per cent of the cultivated land falls within these classes.

Table 10 also shows that 9.4 per cent of the watershed area is in land capability classes VI and VII (not recommended for cultivation). Class IV land which can be cultivated only 1 year in 6 occupies 4.0 per cent of the area. Only 1.4 per cent of the land now being cropped in the watershed is class IV land.

Table 11 shows the land use history in Prairie Township.

## EROSION

<u>General.</u> Two kinds of water erosion occur in the watershed: sheet erosion and channel erosion. In developing any type of watershed treatment program for protection of a reservoir, it is. of primary importance to know where sediment is coming from and how much of the sediment is actually getting down to the reservoir.

The degree of erosion that has taken place in the watershed was mapped by comparing the thickness of different soil layers with that of similar soils and slopes in locations protected from erosion. The following erosion groups were mapped:

<u>No apparent erosion:</u> Approximate original depth of topsoil still remains.

<u>Slight to moderate erosion:</u> Over seven inches of original topsoil remaining, no subsoil exposed by plow.

TABLE 6

Estimated Crop Yields in Carthage Watershed As Related to Soils

| Soils | Per cent Watershed | Management System | Average Yields Bushels per Acre* | | | |
|---|---|---|---|---|---|---|
| | | | Corn | Wheat | Oats | Soybeans |
| 1. Moderately Well Drained Prairie Soils | 15.6 | Good | 62 | 23 | | 24 |
| | | Fair | 57 | 24 | 36 | 24 |
| 2. Imperfectly Drained Soils | 15.7 | Good | 51 | 22 | 45 | 26 |
| | | Fair | 45 | 21 | 42 | 23 |
| 3. Poorly Drained Prairie Soils | 63.9 | Good | 69 | 28 | 44 | 26 |
| | | Fair | 62 | 23 | 37 | 23 |
| 4. Well Drained Timber Soils | 1.5 | | N | N | N | N |
| 5. Poorly Drained Claypan Soils | 1.5 | Good | 50 | 22 | 36 | 20 |
| | | Fair | 41 | 18 | 32 | 17 |
| 6. Bottomlands | 1.9 | | D | D | D | D[2] |

[1] Not adapted.

[2] Subject to high risk from flooding.

*Crop yields were estimated from data in Illinois Agricultural Experiment Station, Bulletin No. 522, entitled, "How Productive Are the Soils of Central Illinois" by R. T. O'Dell.

TABLE 7

Distribution of Slope Classes in Each Soil Group

| Soil Group | A Slopes 0-1½% | | B Slopes 1½-4% | | C Slopes 4-7% | | D Slopes 7-12% | | E Slopes Over 12% | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) |
| 1. Moderately well drained prairie | 30.2 | 2.3 | 166.6 | 73.6 | 103.5 | 59.4 | | | | | 300.3 |
| 2. Imperfectly drained soils | | | 41.9 | 18.5 | 70.1 | 40.2 | 79.1 | 100.0 | 111.9 | 79.8 | 303.0 |
| 3. Poorly Drained Prairie | 1235.8 | 94.2 | | | | | | | | | 1235.8 |
| 4. Well drained timber soils | | | | | .7 | 0.4 | | | 28.2 | 20.2 | 28.9 |
| 5. Poorly drained claypan soils | 11.3 | .8 | 17.9 | 7.9 | | | | | | | 29.2 |
| 6. Bottomlands | 35.5 | 2.7 | | | | | | | | | 35.5 |
| TOTAL | 1312.8 | 100.0 | .226.4 | 100.0 | 174.3 | 100.0 | 79.1 | 100.0 | 140.1 | 100.0 | 1932.7 |

TABLE 8

Distribution of Present Land Use in Each Soil Group

| Soil Group | Cropland | | Pasture | | Miscellaneous | | Total |
|---|---|---|---|---|---|---|---|
| | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) |
| 1. Moderately well drained prairie | 187.7 | 13.1 | 107.6 | 22.8 | 5.0 | 17.0 | 300.3 |
| 2. Imperfectly drained soils | 68.6 | 4.8 | 227.7 | 48.4 | 6.7 | 22.8 | 303.0 |
| 3. Poorly drained prairie | 1156.2 | 80.7 | 61.9 | 13.2 | 17.7 | 60.2 | 1235.8 |
| 4. Well drained timber soils | 1.7 | 0.1 | 27.2 | 5.8 | | | 28.9 |
| 5. Poorly drained claypan soils | 18.5 | 1.3 | 10.7 | 2.3 | | | 29.2 |
| 6. Bottomlands | | | 35.5 | 7.5 | | | 35.5 |
| TOTAL | 1432.7 | 100.0 | 470.6 | 100.0 | 29.4 | 100.0 | 1932.7 |

TABLE 9

Distribution of Present Land Use in Each Slope Class

| Slope Class | Cropland | | Pasture | | Miscellaneous | | Total | |
|---|---|---|---|---|---|---|---|---|
| | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) | (%) |
| A (0-1½ per cent) | 1187.0 | 82.9 | 107.0 | 22.7 | 18.8 | 63.9 | 1312.8 | 67.9 |
| B (1½-4 per cent) | 149.4 | 10.4 | 72.0 | 15.3 | 5.0 | 17.0 | 226.4 | 11.7 |
| C (4-7 per cent) | 72.7 | 5.1 | 98.2 | 20.9 | 3.4 | 11.6 | 174.3 | 9.0 |
| D (7-12 per cent) | 20.4 | 1.4 | 57.2 | 12.2 | 1.5 | 5.1 | 79.1 | 4.1 |
| E (Over 12 per cent) | 3.2 | .2 | 136.2 | 28.9 | 0,7 | 2.4 | 140.1 | 7.3 |
| TOTAL | 1432.7 | 100.0 | 470.6 | 100.0 | 29.4 | 100.0 | 1932.7 | 100.0 |

Moderately severe erosion: Occasional to frequent exposure of subsoil by plow, three inches to seven inches of topsoil remaining.

Severe erosion: Erosion of the subsoil, less than three inches of surface soil remaining.

Very severe erosion: Frequent gullies, too deep to cross with farm implements and very severe erosion that has penetrated into parent material.

Erosion by sheet wash and erosion by channel flow were mapped separately during the course of the conservation survey, as was deposition on fioodplains and in channels.

No apparent erosion has occurred on 63.2 per cent of the watershed. Slight to moderate erosion has occurred on 28.8 per cent and moderately severe erosion on 7.4 per cent of the watershed. Severe erosion has occurred on 0.6 per cent of the watershed. Severe and moderately severe erosion has occurred on soils of groups 1, 2 and 4. (See Table 12)

The distribution of erosion in relation to slopes is shown in Table 13. Slight to moderate erosion has occurred on all slopes with the largest percentage on B slopes. Moderately severe and severe erosion has occurred on B, C, D, and E slopes, while very severe erosion is confined to C, D, and E slopes. Figure 12 shows on eroded permanent pasture in the drainage area. Figure 13 shows a badly eroded feedlot.

The volume of sediment that is being produced at the present time by sheet erosion can be computed directly from the physical land conditions and cropping patterns which exist in the watershed. This method is based on available research data.

The basic data for computing damage from sheet erosion consists of the following:

a. Annual soil losses in tons per acre for soil with an erodibility factor of 1.0, under continuous corn, with and without conservation practices for various per cent and length of slopes.
b. Factors for computing the effects of cropping patterns and soil types on soil losses.

TABLE 10

Land Use Capability Classes Compared With Existing Land Use

| | Cropland | | Pasture | | Miscellaneous | | Total | |
|---|---|---|---|---|---|---|---|---|
| | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) | (%) |
| Class I'Land<br>Suitable for cultivation, requiring no erosion control practices to maintain soil for general agricultural practices | 1177.6 | 82.2 | 69.6 | 14.8 | 18.8 | 63.9 | 1266.0 | 65.5 |
| Class II Land,<br>Good land that can be cultivated safely with easily applied practice. | 149.7 | 10.4 | 65.1 | 13.8 | 5.0 | 17.0 | 219.8 | 11.4 |
| Class III Land<br>Moderately good land that can be cultivated safely with such intensive treatments as terracing and strip cropping | 78.6 | 5.5 | 106.3 | 22.6 | 2.8 | 9.5 | 187.7 | 9.7 |
| Class IV Land<br>Best suited to hay or pasture, but can be cultivated occasionally, usually not more than 1 year in 6 | 19.5 | 1 .4 | 65.4 | 12.0 | 2.1 | 7.2 | 78.0. | 4.0 |
| Class VI Land<br>Not recommended tor cultivation. Best suited for permanent pasture | 7.3 | .5 | 70.3 | 36.2 | .7 | 2.4 | 178.3 | 9.2 |
| Class VII Land<br>Not recommended lor cultivation. Suited for woodland or pasture with major restrictions in use | | | 2.9 | 0.6 | | | 2.9 | 0.2 |
| TOTAL | 1432.7 | 100.0 | 470.6 | 100.0 | 29.4 | 100.0 | 1932.7 | 100.0 |

TABLE 11

Land Use, Prairie Township, Hancock County, Illinois 1938-49[1]

| Year | Number of Farms | Acres per Farm | | Per cent of Cropland In: | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total | Cropland | . Corn | Soybeans | Small Grain | Hay | Other Crops | Plowland Idle or Failure |
| 1938 | 142 | 138 | 115 | 32 | 16 | 28 | 23 | .... | 1 |
| 1939 | 137 | 142 | 116 | 30 | 22 | 24 | 22 | .... | 2 |
| 1940 | 138 | 147 | 119 | 27 | 21 | 20 | 30 | .... | 2 |
| 1941 | 141 | 143 | 112 | 30 | 23 | 23 | 21 | .... | 3 |
| 1942 | 137 | 151 | 120 | 28 | 17 | 28 | 24 | 1 | 2 |
| 1943 | 126 | 164 | 129 | 33 | 31 | 16 | 18 | 1 | 1 |
| 1944 | 129 | 152 | 128 | 34 | 32 | 9 | 22 | .... | 3 |
| 1945 | 120 | 167 | 124 | 30 | 40 | 17 | 13 | .... | .... |
| 1946 | 115 | 171 | 123 | 38 | 31 | 20 | 11 | .... | .... |
| 1947 | 116 | 178 | 122 | 34 | 36 | 17 | 13 | .... | .... |
| 1948 | 111 | 170 | 126 | 40 | 22 | 28 | 10 | .... | .... |
| 1949 | 122 | 157 | 118 | 40 | 19 | 32 | 9 | .... | .... |
| Av. 1942-45 | 128 | 158 | 125 | 31 | 32 | 15 | 20 | .... | 2 |
| Av. 1946-49 | 116 | 169 | 122 | 38 | 27 | 24 | 11 | .... | |
| 12-year Av. 1938-49 | 128 | 155 | 121 | 33 | 27 | 21 | 18 | .... | 1 |

[1] Based on assessor's census of farm acreage.

TABLE 12

Distribution of the Erosion Group in Each Soil Group

| Soil Group | No Apparent Erosion | | Silght to Moderate Erosion | | Moderately Severe Erosion | | Severe Erosion | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) |
| 1. Moderately well drained prairie | 7.7 | 0.6 | 224.2 | 40.3 | 68.4 | 47.8 | | | 300.3 |
| 2. Imperfectly drained soils | | | 228.0 | 41.0 | 63.4 | 44.3 | 11.6 | 94.3 | 303.0 |
| 3. Poorly drained prairie | 1176.1 | 96.4 | 59.7 | 10.7 | | | | | 1235.8 |
| 4. Well drained timber soils | | | 16.9 | 3.0 | 11.3 | 7.9 | .7 | 5.7 | . 28.9 |
| 5. Poorly drained claypan soils | 1.6 | 0.1 | 27.6 | 5.0 | | | | | 29.2 |
| 6. Bottomlands | 35.5 | 2.9 | | | | | | | 35.5 |
| TOTAL | 1220.9 | 100.0 | 556.4 | 100.0 | 143.1 | 100.0 | 12.3 | 100.0 | 1932.7 |

TABLE 13

Distribution of Erosion Groups in Each Slope Class

| Slope Group | No Apparent Erosion | | Slight to Moderate Erosion | | Moderately Severe Erosion | | Severe Erosion | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) |
| A (0-1½ per cent) | 1220.9 | 100.0 | 91.9 | 16.5 | | | | | 1312.8 |
| B (1½-4 per cent) | | | 219.4 | 39.4 | 7.0 | 4.9 | | | 226.4 |
| C (4-7 per cent) | | | 75.6 | 13.6 | 94.2 | 65.8 | 4.5 | 36.6 | 174.3 |
| D (7-12 per cent) | | | 46.8 | 8.4 | 27.4 | 19.1 | 4.9 | 39.8 | 79.1 |
| E (Over 12 per cent) | | | 122.7 | 22.1 | 14.5 | 10.2 | 2.9 | 23.6 | 140.1 |
| TOTAL | 1220.9 | 100.0 | 556.4 | 100.0 | 143.1 | 100.0 | 12.3 | 100.0 | 1932.7 |

c. The cropping pattern and the total acreage in each soil group by per cent and length of slope and degree of erosion.

The annual soil loss ("a" above) multiplied by the appropriate cropping pattern factor and soil factor, gives the annual soil loss in tons per acre. This loss, converted to acre-inches and multiplied by the acreage on which it occurs, gives the annual volume of sediment in acre-inches produced by this source.

Table 15 presents a summary of above computations which indicates that under present practices (without an applied conservation program) the soil loss from sheet erosion amounts to 7,343 tons per year. Assuming a weight of 1,800 tons per ' acre-inch, this loss amounts to 4.08 acre-feet per year.

Gully Erosion. In order to estimate the importance of gullies as a sediment source and also as a destructive agent to farm operations in the Carthage Reservoir Watershed, a particular effort was made to locate, measure, and describe every gully.

All gullies that could not be crossed with conventional farm machinery were studied by the conservation surveyor in the field. The location of the gully and measurements thus determined were recorded on a transparent overlay on the aerial photograph.

Thirty-six gullies were located and described, the largest being 15 feet deep, 20 feet wide and 825 feet long. This single gully in its lifetime has produced over 6 acre-feet of sediment and has made void over one-third acre of land. It was possible to locate the head of twenty of the gullies on aerial photographs taken in 1938. By pinpointing the head of the gully at its 1938 location and its 1949 location, an accurate measurement of the growth in length of the gully was obtained. Sixteen of the gully heads could not be accurately located on the 1938 photos, being, in many cases, obscured by brush or trees.

The length of growth since 1938 and present cross-sectional areas indicate that a volume amounting to 137,391 cubic-feet of material has been removed from the twenty gullies since 1938 by head growth.

Assuming that the twenty observed gullies are an accurate sample, the following is evident:

137,391 cubic feet = amount from 20 gullies in 11 years.

22,482 cubic feet = amount per year by head growth of all gullies.

The area damaged by headward growth of gullies was computed by the same process. The twenty gully sample indicates that 44,965 square feet of land surface has been voided by this growth. The total area is computed:

$$36 \times \frac{44{,}965}{20} = 80{,}928 \text{ square feet.}$$

The average annual area = 7,357 square feet, or 0.17 acre.

Uncontrolled gullies grow wider, deeper and longer. Accurate records of gully widths and depths in the past are not available in the Carthage area. In order to estimate accurately the total volume of sediment produced and the area affected by gullies, a number of detailed gully growth studies have been made by the Soil Conservation Service. In the Missouri Basin Loess Hills (where soil materials and topography are similar to those at Carthage) these studies[7] indicate that "head growth" represents approximately 64 per cent of the volumetric growth and 62 per cent of the areal growth of these type of gullies.

By applying these percentage factors, the following estimates were derived for the watershed above Carthage reservoir.

Gullies produce 35,128 cubic-feet (0.81 acre-foot) of sediment and 11,866 square feet (0.27 acre) of surface are voided annually.

[7] Unpublished data. U.S.D.A. Soil Conservation Service. Milwaukee, Wisconsin.

Although volumetric data were not obtained, survey notes were made to indicate that uncontrolled streambank erosion is taking place at the numerous bends of the stream above the lake.

Erosion of roadside ditches, while a minor sediment source, contribute to the action of several major gullies. These roadside ditches should be controlled as part of a waterway stabilization program.

From Table 11 it can be computed that 78 per cent of the farm land is used for crops. Since 86.6 per cent of the area is safe for continuous safe cultivation, it is obvious that major reductions in cultivated acreage will not be necessary. The conservation survey data shown in Table 14, indicate that a large per cent of the moderate and severe erosion was found in pastures.

Sources of Sediment. The watershed study indicates that sheet erosion is producing an estimated 4.08 acre-feet of sediment and gully erosion an additional 0.81 acre-feet of sediment each year. Roadside ditches and streambank erosion are estimated to produce approximately 0.1 acre-foot annually.

At the present time the 96.3 acres of C, D and E slopes which are cultivated produce an estimated 3,738 tons of sediment from sheet erosion each year, compared to 3,605 tons originating from sheet erosion on the remaining 1,836 acres in the watershed. It is interesting to note that these critical areas produce sediment at an estimated rate of approximately 39 tons per acre per year compared to approximately 2 tons per acre per year from the less critical areas.

The various types of erosion in the watershed produce approximately 5.0 acre-feet of sediment annually. The annual

TABLE 14

Distribution of Erosion Groups in Each Land Use Class

| Land Use Class | No apparent Erosion | | Slight to Moderate Erosion | | Moderately Severe Erosion | | Severe Erosion | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) | (%) | (acres) |
| Cropland | 1107.9 | 90.7 | 235.2 | 42.3 | 82.3 | 57.5 | 7.3 | 59.3 | 1432.7 |
| Pasture | 95.3 | 7.8 | 312.4 | 56.1 | 58.5 | 40.9 | 4.4 | 35.8 | 470.6 |
| Miscellaneous | 17.7 | 1.5 | 8.8 | 1.6 | 2.3 | 1.6 | .6 | 4.9 | 29.4 |
| TOTAL | 1220.9 | 100.0 | 556.4 | 100.0 | 143.1 | 100.0 | 12.3 | 100.0 | 1932.7 |

TABLE 15

Estimated Reduction in Sheet Erosion Annually From a Watershed Treatment Program

Lake Carthage

Tons of Soil Lost

Without Program

| Slope | Cultivated (acres) | Tons/Acre | Tons Lost | Pasture (acres) | Tons/Acre | Tons Lost |
|---|---|---|---|---|---|---|
| A | 1,187 | 2.0 | 2,374 | 125.8 | 0 | 0 |
| B | 149.4 | 6.7 | 1,000 | 77.0 | .4 | 31 |
| C | 72.7 | 31.0 | 2,245 | 101.6 | .6 | 61 |
| D | 20.4 | 63.0 | 1,265 | 58.7 | .6 | 35 |
| E | 3.2 | 79.0 | 238 | 136.9 | .6 | 84 |
| Subtotal | | | 7,132 | | | 211 |
| Total Tons Lost | | | | | | 7,343 |

With Recommended Program

| Slope | Cultivated (acres) | Tons/Acre | Tons Lost | Pasture (acres) | Tons/Acre | Tons Lost |
|---|---|---|---|---|---|---|
| A | 1,187 | 1.0 | 1,187 | 125.8 | 0 | 0 |
| B | 149.4 | 3.0 | 448 | 77.0 | .1 | 8 |
| C | 72.7 | 4.0 | 289 | 101.6 | .2 | 20 |
| D | | | | 79.1 | .2 | 16 |
| E | | | | 140.1 | .2 | 28 |
| Subtotal | | | 1,924 | | | 72 |
| Total Tons Lost | | | | | | 1,996 |

Total soil loss reduced 72.8 per cent due to watershed program.

accumulation in the lake is only 4.19 acre-feet. The difference of about 0.8 acre-foot is assumed to be deposited in colluvial areas, on floodplains, and in channels upstream from the lake, and to pass over the dam in suspension.

## CONSERVATION

Land use adjustments and conservation practices are needed in the watershed both to develop a more permanent and profitable agriculture and to reduce the rate of sedimentation in Lake Carthage.

Lake Carthage has a relatively small watershed. Only one conservation plan is in operation in the watershed, and one plan is in the farm planning stage. Relatively good rotations have been used on much of the cropland in the reservoir watershed. The legume acreage has not been up to the standards of land use capability requirements nor up to a desired level. Clover stands are sparse in some instances and would be much better if the soil were tested and the proper amounts of limestone and fertilizer were applied.

Only two farms in the watershed have any contouring. Sheet erosion and runoff of the water occur on corn and soybean fields and small grain fields which are planted up and down the hill. Most of the crop fields do not have steep slopes. Some of the present cropland should be in permanent pasture. The land use pattern could stand considerable improvement.

The present permanent pastures need improvement. Soil treatment, including applications of limestone, phosphate, and potash, is needed. Reseeding and renovation are also needed on many of the pastures. In many instances brush should be grubbed out and trees and hedge in the permanent pastures should be removed. Very few of the permanent pastures are mowed, and in general they are weedy. The permanent pastures are probably less than 50 per cent as productive as could reasonably be expected. Many of them are only exercise lots, particularly during the summer months. It is quite apparent that alfalfa-brome grass is suitable in this area. In a few instances some of the present area in permanent pasture might better be in trees; livestock, of course, should be kept out of these wooded areas.

The waterways in much of the watershed should be shaped, treated according to soil test and seeded. Some of the draws should be planted to trees and livestock fenced out. Numerous drop boxes and some soil-saving dams are needed in the waterways leading to the reservoir.

# RESULTS

## CAUSE OF HIGH RATE OF STORAGE LOSS

Watershed Factors. The average annual sediment accumulation in Lake Carthage amounts to 4.19 acre-feet, as shown by the survey. From studies in reservoirs where both sediment accumulation and sediment discharge were obtained, it is estimated that this reservoir has a trap efficiency of 93 per cent. It follows then that an average of 4.50 acre-feet of sediment is being produced on the watershed; 4.19 acre-feet remaining in the reservoir and 0.31 acre-feet going over the spillway.

As indicated in previous paragraphs, 0.81 acre-feet of sediment (18 per cent of the total) is being produced each year from gullies.

It is estimated that sediment originating from sheet erosion makes up the bulk of the sediment, probably about ± 3.60 acre-feet per year.

Sediment from streambanks, bottomland scour, and roadside ditches is a minor part of the total.

## REMEDIAL MEASURES

Practicability. The need for action regarding the water source for Carthage has been shown earlier in this report in Figure 10. It is seen that some action will be necessary soon to avert a possible water shortage within the next four years. Action is needed to safeguard the city against droughts which can be expected to concur at much greater recurrence intervals, possibly once in 25 or once in 50 years. Figure 10 shows that the application of a watershed conservation program will not protect the lake from a water shortage till the year 1975, and the effect would be relatively small at that time. A serious shortage could occur in any year. Lake Carthage is now inadequate to serve the growing community and the water supply must be augmented in some way. Consequently early consideration should be given to possible remedial measures before a shortage occurs.

Raising the Dam. One of the first steps usually considered by lake owners in increasing storage capacity is the raising of the spillway and possibly the entire dam. Such action is usually subject to limitations because the original dam and spillway were probably designed to give the most economical project available at that site. Limited increase in storage space can often be gained in this manner and such action should be considered.

Other Lakes. In searching for additional storage space, additional reservoir sites should be considered. In past studies, reservoir sites on Long Creek and the Lamoine River have been investigated and possibly the development of additional surface storage capacity at one of these sites should be given consideration at the present time.

Dredging. Reservoir owners faced with a sedimentation problem sometimes resort to dredging to remove the sediment and regain storage space. The unit cost of dredging is normally high in comparison to other methods of regaining or providing additional storage. Dredging has proven to be worthwhile in some cases where deltas of sediment or local shallows have formed within the lake which ruined the aesthetic properties of the lake.

The City of Macomb has recently carried out dredging operations to remove sediment from their municipal reservoir.

Vegetative Plantings. In some cases on record sedimentation in a reservoir has been partially relieved by the introduction of thick growing vegetative screens into the delta areas in the upper part of the lake. The total effect of such planting however in reducing the total volume of sediment reaching the reservoir can be considered minor in comparison to a program ot erosion control covering the entire watershed. Proper soil treatment, adequate crop rotation, and a sound pasture renovation and management program are essential in this watershed to control soil movement. The planting of trees and shrubs in particular areas suited for woodland or wildlife is highly desirable. The local Farm Adviser or Soil Conservation District personnel should be consulted for the best location of such plantings and the species to be planted.

## WATERSHED TREATMENT PROGRAM

Needed Measures. One of the methods of affecting a permanent reduction in the rate of sediment inflow to Lake Carthage is the establishment of an intensive land treatment program on the watershed to control sheet erosion on the farmland. Because of the seeming feasibility of establishing such a conservation program on the Lake Carthage Watershed, an in-

FIG. 12. ERODED PERMANENT PASTURE IN WATERSHED. No Soil Treatment, Poor Stand and Negligible Production, Feed Lot on Slope in Background.

vestigation has been made of the elements of such a program and the possible benefits.

By study of the conservation survey data, it is possible to estimate the annual soil loss from sheet erosion in this watershed and the probable reduction that can be accomplished under a land treatment program.

The most striking fact revealed by the conservation survey data is that more than one-half of the sediment produced to date in this watershed has originated from areas now used for pastures. When it became uneconomical to grow crops on the steeper slopes they were "retired." Apparently little thought has been give to the potential pasture thus attained, nor effort expended to more effectively utilize these areas by seeding, fertilizing, mowing, etc. to gain the potential yields thus available.

The major recommended change in land use is the conversion of 23.7 acres of cultivated land on D and E slopes to permanent pasture or hay. The crop rotations now being followed in the watershed cannot be considered adequate either to maintain production or stabilize soil. Prom Table 15 it is evident that the 72.7 acres of C slope now in cultivation produce nearly as much sediment as 1,187 acres of A slope. Contour cultivation with supplementary soil and water conservation practices, such as diversion ditches and terraces, are needed badly for these areas. The more nearly level area, A and B slopes, should be farmed in accordance with its use capability. This would require more legumes and close growing crops than are used at the present time.

Structures. In order to control the velocity of the runoff water in the gullies, structures may be needed. The Soil Conservation Service has found pipe drop inlet spillways to have the advantage of construction economy and efficiency of operation in this area. Structures accomplish two objectives, (a) control head growth, and (b) control the velocity of the run-off water so that vegetation can be established to stop the gullies from growing deeper and wider.

Incidental to the control of gullies, but a tangible benefit, is the farm pond sometimes created above the structure. Properly designed, these ponds will have the effect of stablizing the run-off, as well as augmenting the local water supply.

Probable Present Annual Soil Loss. Table 15 shows the estimated amount of soil lost from the watershed each year under present land use practices. Under present conditions, the total soil loss from sheet erosion is calculated to be 7,343 tons per year. To establish this estimate, a review was made of the land use followed during the past four years (1946-1949). This showed that a rotation of corn, corn, corn, small grain, and hay (3-1-1) was followed on 65 per cent of the area; corn or soybeans—small grain with a sweet clover catch crop on 26 per cent of the area; and straight corn on 9 per cent of the area. Soybeans are substituted for corn in over half of the above rotation. Soil losses from steep pasture was estimated to be 0.6 tons per acre per year. This is a very high estimate, but is justified by the poor cover found on the pastures and the numerous paths and trampling.

Probable Soil Loss Under Proposed Program. Table 15 shows that the present annual soil loss, from sheet erosion, 7,343 tons, could be reduced to approximately 1,996 tons, or 72.8 per cent. The program recommended to bring about such a reduction is based on standard land use capability recommendations and slope-practice data of the Soil Conservation Service.

The amount of reduction of sediment reaching the lake achieved by the adaption of soil conservation practices will depend on the completeness of application. There is little question that the changes in land use that are recommended to bring these areas within the recommended use according to their capability is practical. Referring to Table 10, it can be seen that the 26.8 acres of land, now cultivated, that are recommended for pasture would be easily offset by using part of the 134.7 acres of Class I and II land now in pasture for cropland.

The economic advantages to the farmer of the use of conservation practices is becoming known in the area and their early adaption and widespread use is anticipated.

Reduction of Sediment Reaching Lake. Since sheet erosion is credited with 82 per cent of the total sediment in the reservoir, the reduction by 72.8 per cent thus achieved will result in a 59.7 per cent reduction of the sediment entering the reservoir.

Gullies produce an estimated 16 per cent of the total sediment entering Lake Carthage. For the purpose of further analysis of the effects of a watershed treatment program, it is estimated that with a reasonable amount of control, soil loss from this source can be reduced by one-half. This reduction would result in an 8.0 per cent (16 per cent x 50 per cent) reduction in the sediment reaching the lake. No reduction is anticipated in the approximately 2 per cent of the sediment which is derived from other sources.

The combination of the 59.7 per cent reduction by land treatment, and the 8.0 per cent reduction by gully stabilization will effect a total reduction of 67.7 per cent of the sediment inflow

FIG. 13. CATTLE IN BADLY ERODED FEEDLOT ON STEEP SLOPE DRAINING DIRECTLY INTO LAKE CARTHAGE. Manure, Soil Are Washed into the Lake With Every Rain.

into the lake. The rate of storage loss would thus be reduced from 1.03 per cent to 0.32 per cent per year. The volume of sediment reaching the reservoir each year would be reduced from 4.99 acre-feet to 1.61 acre-feet; 1.35 acre-feet of which would be retained in the reservoir.

Extension of Life of Lake. The effect of this 67.7 per cent reduction of sediment inflow into the lake is shown on the graphs in Figures 9 and 10 earlier in this report, It is noted from Figure 10 that the soil conservation program even though initiated in the watershed at the present time would have no great effect in protecting the lake against sediment accumulations until about the year 1970 when the effectiveness of the reduced sedimentation would be significant.

This does not mean that the rate of sedimentation could not be reduced until 1970. For use in Figure 10, it is estimated that if such a conservation program were begun in the year 1953 it could be completed in the year 1958 and that the entire 67.7 per cent reduction would take effect in the year 1958. In Figure 10 the increase in total water consumption in future years is the controlling factor causing the water shortage to occur. In this case even though sedimentation in the lake were reduced by this percentage, the shortage would nevertheless occur.

In Figure 9 of this report has been shown the decrease in reservoir capacity under the present rate of sedimentation. In Figure 9 has also been plotted the reduction in rate of sedimentation in future years if the above described watershed treatment program were installed and were to take effect in the year 1958. It is evident from Figure 9 that the installation of such a conservation program will reduce the actual rate of loss of capacity in the lake. Thus the ultimate life of Lake Carthage will be increased considerably even though the useful life of the lake may not be increased to a significant degree. For this reason as well as the benefit to the land itself, the City should consider means of bringing about the application of this watershed program:

The conservation measures needed in this watershed are measures similar to those needed throughout Hancock County as well as the entire state and nation to provide for a more permanent and productive agriculture. The Hancock County Soil Conservation District has as its objective the application of these measures within the county. Technical assistance is given the District by the Soil Conservation Service, Extension Service and other federal and state agencies. The District is authorized to accept aid from any source in carrying out its program. Efforts of the City Water Department to establish a watershed treatment program could very reasonably be carried out through this District.

The City of Decatur, faced with a serious reservoir sedimentation problem, has maintained for many years a trained conservationist to work only on the reservoir watershed. This man, paid entirely from city funds, gives technical help to farmers in the area in a manner similar to that furnished all farmers by the soil conservation district and the Soil Conservation Service. The City of Springfield maintains its own nursery for furnishing seedlings lor planting on city-owned property around Lake Springfield. The City of Macomb is aiding the local soil conservation district in an increased effort to apply needed conservation measures on the city reservoir watershed.

Many cities within the country have found it economical to purchase all or much of the reservoir watershed for control. In this manner the city water department can make certain that the control of soil loss is complete. This does not mean that the land is all taken out of cultivation or agricultural use. Such lands are frequently leased to private interests for farming in line with the capabilities of the land. As has been shown, much of the land in the Lake Carthage watershed is suitable for grassland. After purchase, and proper treatment, this land could be leased for pasture. Such programs of watershed control have been found self-supporting and even profitable to the city in many cases[8]. The City ot Akron, Ohio, has carried on such operations profitably.

## COSTS AND BENEFITS OF CONSERVATION

The Carthage Lake watershed consists of 1,933 acres. At the time of the survey, conservation practices had been applied on relatively little of the area. The adoption of a complete plan of soil and water conservation and erosion control on all the land in the Lake Carthage watershed would pay the farmers in the long run. It would also very materially reduce the silting of the lake and greatly prolong its ultimate life.

Present Practices. Rotations on the cropland are more intensive than recommendations based on land-use capability data. For the 12-year period 1938-49, approximately 60 per cent of the cropland was in intertilled crops (corn and soybeans), 21 per cent in small grains, 18 per cent in meadow and one per cent idle. For the four years immediately preceding the survey, 1946-49, 65 per cent of the cropland was in corn and soybeans, 24 per cent in small grains and only 11 per cent in meadow. Thus, while the long-time rotation was approximately a three-one-one, and the past four years a six-two-one, the recommended rotation would be approximately a two-one-two.[9] The better rotation needed on the cropland also would require the use of supporting practices such as grass waterways, contouring, terracing, etc. The land use in the Carthage Lake watershed follows the pattern for the surrounding land area in Hancock County which averaged for the five years 1945-49, 57 per cent of the tilled areas in corn and soybeans, 24 per cent in small grains, 17 per cent in meadow and two per cent idle. The recommended use of cropland for Hancock County, based on land-use capability data, is 40 per cent in intertilled crops, 22 per cent in small grains, and 38 per cent in meadow.

Supporting practices on the cropland, that is, use of grass waterways, contouring and terracing would help materially in retarding runoff and the silting of the lake that comes from sheet erosion. At the present time, most of the crops are planted without regard to slope and considerable sheet erosion and runoff occurs on corn and soybean fields planted up and down the slopes.

Soil fertility treatment, that is, the application of limestone, phosphate and potash in accordance with needs as shown by soil tests, is an important first step in the establishing of a conservation program in this area. While limestone and phosphate requirements have been met on approximately half of the cropland, very little of the pasture land has been treated. It is estimated that approximately 60 per cent of the land area is in need of soil treatment. Adequate soil treatment would result in better stands and growth of legumes and grasses, resulting in not only increased forage production, but also reduced runoff and soil and water losses.

Costs of Conservation. The costs of applying conservation to the land in the Lake Carthage watershed will depend on measures used. If primarily vegetative methods are used, the costs will be approximately $38.00 per acre, for the land that has had no soil fertility treatment.[10] Assuming that 40 per cent

[8] LaDue, Wendell R., Reservoir Lands Pay Their Way—Balanced Use of Reservoir Lands, Journal of American Water Works Association, Vol. 40, No. 8, August, 1948.

[9] The numbers refer to years of intertilled, small grain, and meadow, respectively. The recommended two-one-two rotation thus is corn-corn or soybean-small grain-meadow-meadow.

[10] This assumes average per acre soil treatment of three tons of limestone, three-fourths ton rock phosphate or its equivalent in superphosphate and 200 pounds potash. Soil fertility treatment would thus cost approximately $32.00 per acre, while waterways, seedings, terraces, trees and shrubs would cost an average of $6.00 per acre for the 1,933 acres in the watershed.

of the land area has had soil treatment, average per acre costs of conservation by vegetative methods would be approximately $25.00 per acre of the watershed.

There are 36 major gullies in this watershed. If structures are used to control the velocity of runoff water in the gullies, the costs of conservation will be increased. Gully control structures may be found to be essential in order to retard or prevent silting of the lake, and if so, they would have to be a public expenditure rather than a private or farm owner expenditure. If a sound conservation farm plan were adopted on all of the farms in the watershed, including (1) land use and crop rotations in accordance with soil capabilities, (2) soil fertility treatment in accordance with soil tests, (3) use of supporting practices where needed as waterways, contouring and terracing, (4) the improvement of permanent pastures and use of rotational grazing, (5) the fencing out of woodland and gullies and the planting of trees and shrubs, (6) the relocation of feedlots from sloping hillsides to more level areas, it is reasonable to assume that the silting of Lake Carthage would be greatly reduced.

Studies of costs and benefits of contour farming in this area show that contour farming alone, contour strip cropping, and terracing result in high crop yields and do not increase the overall cost of farm operation. Corn, soybeans, oats and wheat yields were increased 12, 13, 16, and 17 per cent, respectively, from contouring. Labor, power and machinery costs per crop acre averaged $1.58 lower (at 1945 prices) on the farms that were farming on the contour.

Benefits of Conservation. Studies of farm records show that the application of soil conservation measures can be justified economically by the farmer himself because the increased yields of grain and forage crops from conservation farming result in increased farm income.

On a practical, tenant-operated, livestock and grain farm in this area, on land similar to that in the Lake Carthage watershed, conservation farming has resulted in increased production and net farm income. Operating under a livestock-share lease, the landlord and tenant have shared in both the costs and benefits of their conservation program. Approximately 70 per cent of their farm is tillable. They use a five-year corn-corn and soybeans-small grain-alfalfa bromegrass-alfalfa bromegrass rotation. Since completing limestone and phosphate applications to correct basic deficiencies, they are spending approximately $2.00 per acre per year for fertilizers etc. for maintenance and improvement of the land. Before starting the conservation program, their crop yields were about equal to the county average. Now their corn is yielding 20 bushels an acre above the county average and yields of their other crops have improved accordingly. Their net farm income is averaging 10 per cent above the average of all farm-account keeping farms in Hancock County.

Another example of land use, production and income before and after a program ot conservation was adopted on an individual farm and covering a 10-year period shows that all crops yielded only 94 per cent of the county average before the program was started and increased to 114 per cent afterwards—a gain of 20 per cent. This gain in yields from reducing the acreage of intertilled crops and increasing the acreage of legumes and grasses, plus other recommended conservation practices, brought an annual return of $696.00 more from grain crops or $1,019.00 more from all crops for each 100 acres of cropland.

Long-time Economic Results of Conservation Farming. A summary of 10 years of data on 80 high- and 80 low-conservation farms in Illinois shows increased earnings on the high-conservation farms resulted from the adoption of soil conservation and fertility improvement practices and from the improvement of the general level of the management of the farm. At 1945 prices, the 10-year average increases in earnings from the high-conservation farms compared to low-conservation farms average $6.05 an acre. Capitalizing this increased income at five per cent, the value of the land on the high-conservation farms would be increased by $121.00.

Economics of Conservation. Results ot 16 years of research show that conservation farming not only protects soil and water resources, but also increases tarm production and income. Although some conservation measures increase production the first year, conservation plans do not necessarily increase earnings immediately. Often a considerable amount of effort and money must be expended before positive results are achieved. If the land has been poorly handled in the past, several years may be required to restore its productivity andearning power to a satisfactory level. The long-time benefits of conservation are certain, however.

## RECOMMENDATIONS

It is recommended that the City of Carthage engage a qualified professional engineer to investigate the adequacy of the present water supply system to furnish the present and future needs of the city and to report on the most economical method for maintaining an adequate water supply.

It is recommended that the City of Carthage undertake immediately the application of a watershed treatment program on the drainage area of Lake Carthage to reduce sedimentation and prolong the ultimate life of this lake and the length of time it can be used for the public water supply. It is suggested that this program be carried out by (1) financial assistance from the City to a local Soil Conservation District for intensified conservation efforts on this watershed or (2) purchase of the watershed or much of the critical erosion area by the City for application of the needed conservation measures.

REPORTS OF INVESTIGATIONS
ISSUED BY THE STATE WATER SURVEY

No. 1. Temperature and Turbidity of Some River Waters in Illinois. 1948.

No. 2. Groundwater Resources in Winnebago County, with Specific Reference to Conditions at Rockford. 1948.

No. 3. Radar and Rainfall. 1949.

No. 4. The Silt Problem at Spring Lake, Macomb, Illinois. 1949.*

No. 5. Infiltration of Soils in the Peoria Area. 1949.

No. 6. Groundwater Resources in Champaign County. 1950.

No. 7. The Silting of Ridge Lake, Fox Ridge State Park, Charleston, Illinois. 1951.*

No. 8. The Silting of Lake Chautauqua, Havana, Illinois. 1951.

No. 9. The Silting of Carbondale Reservoir, Carbondale, Illinois. 1951.*

No. 10. The Silting of Lake Bracken, Galesburg, Illinois. 1951.

No. 11. Irrigation in Illinois. 1951.

No. 12. The Silting of West Frankfort Reservoir, West Frankfort, Illinois. 1951.

No. 13. Studies of Thunderstorm Rainfall with Dense Raingage Networks and Radar. 1952.

No. 14. The Storm of July 8, 1951 in North Centra! Illinois. 1952.

No. 15. The Silting of Lake Calhoun, Galva, Illinois. 1952.

No. 16. The Silting of Lake Springfield, Springfield, Illinois, 1952.

No. 17. Preliminary Investigation of Groundwater Resources in the American Bottom. 1953.

No. 18. The Silting of Lake Carthage, Carthage, Illinois. 1953.

*Out of print.